

**Fig.1A**  
**(PRIOR ART)**

2/49

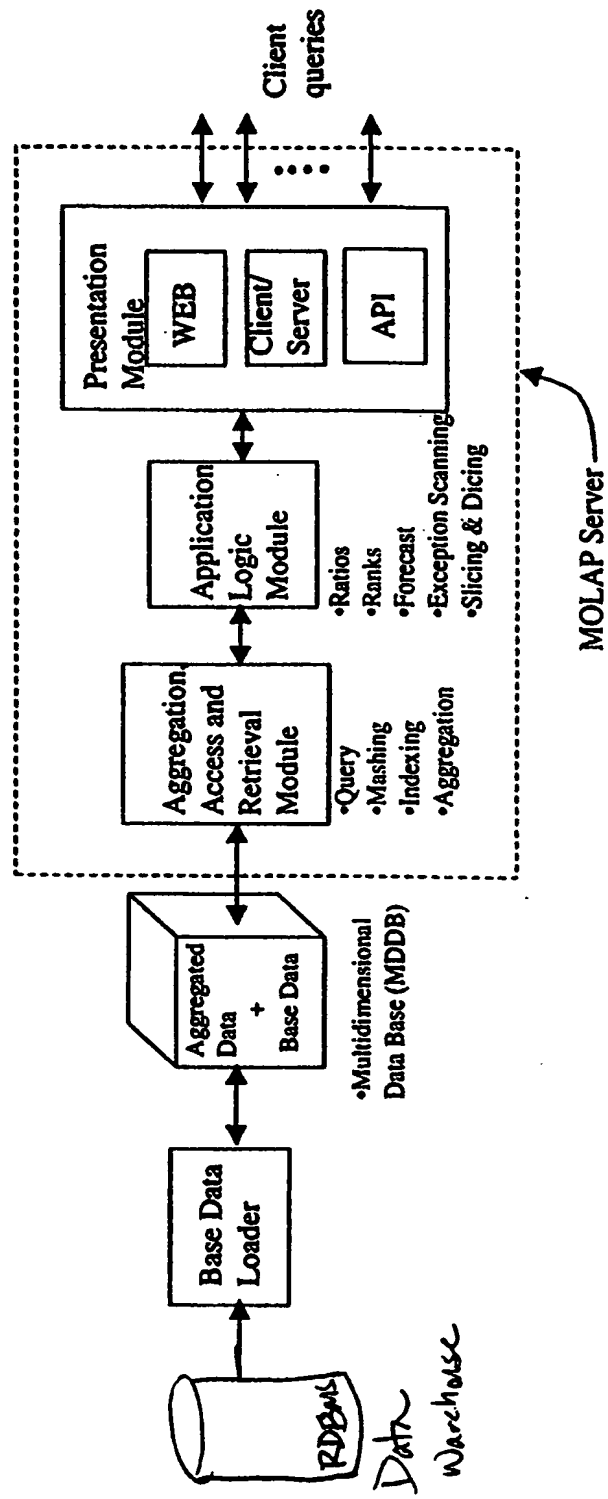
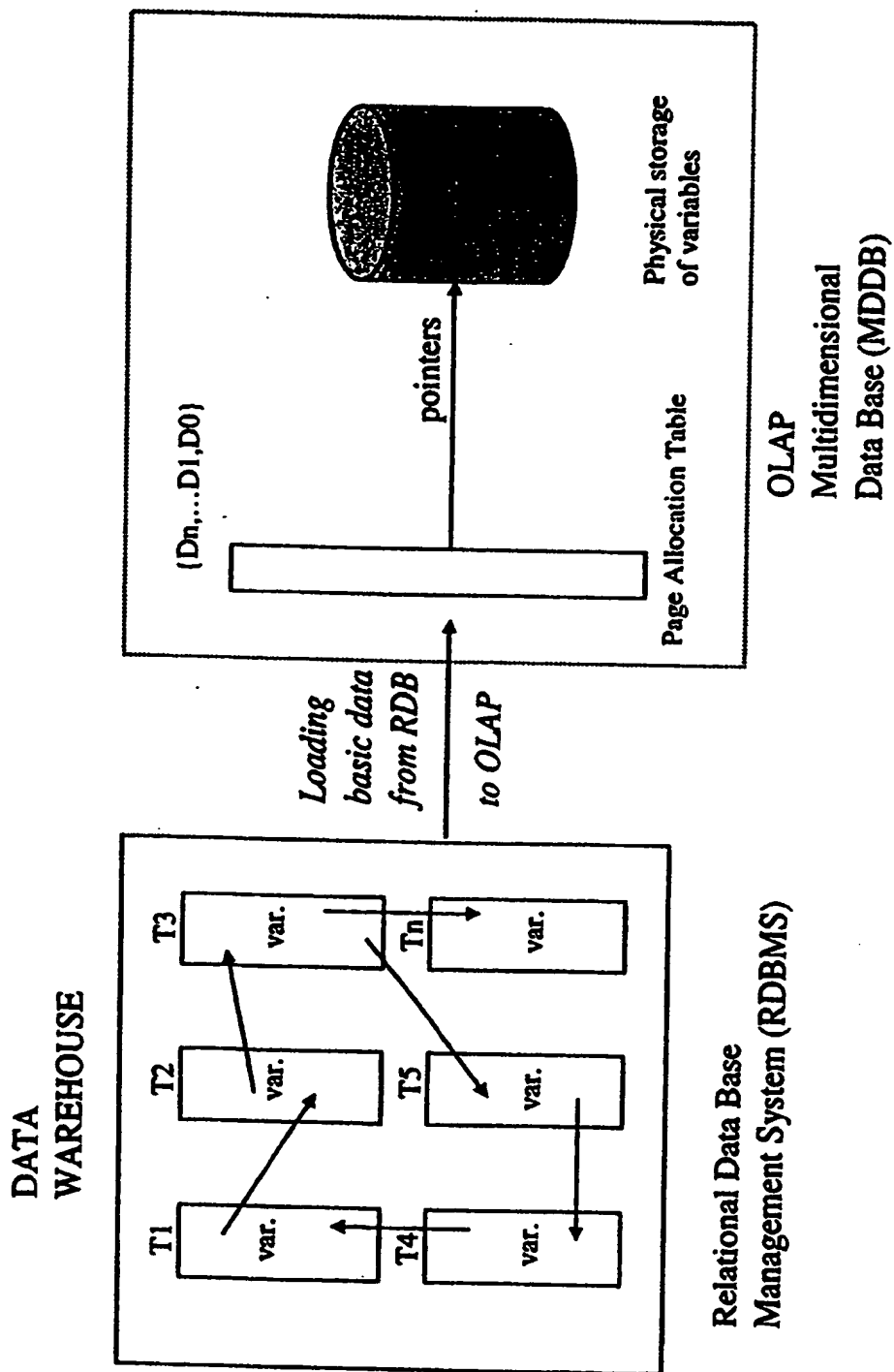


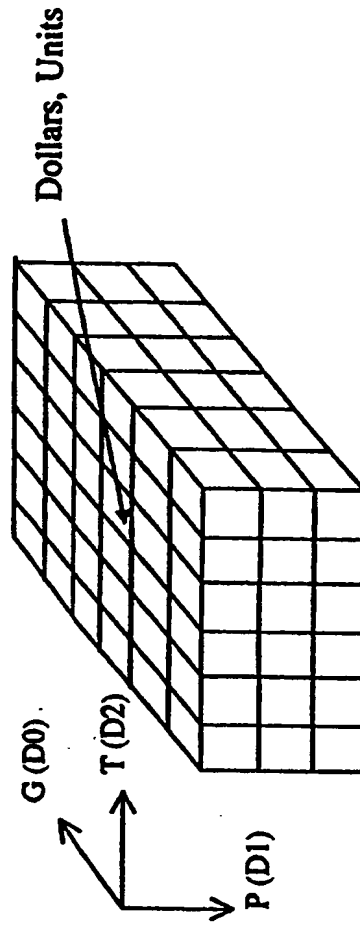
FIG. 1B

3/49



**Fig. 2A**  
**(PRIOR ART)**

4/49



G geography (e.g. cities, states, countries, continents)  
T time (e.g., days, weeks, months, years)  
P products (e.g. all products, by manufacturer)

**Fig. 2B**  
**(PRIOR ART)**

5/49

Page Allocation Table pointing on physical records of a multidimensional variable (e.g. the two first rows of a variable of FIG. 2B reside in page # 0)

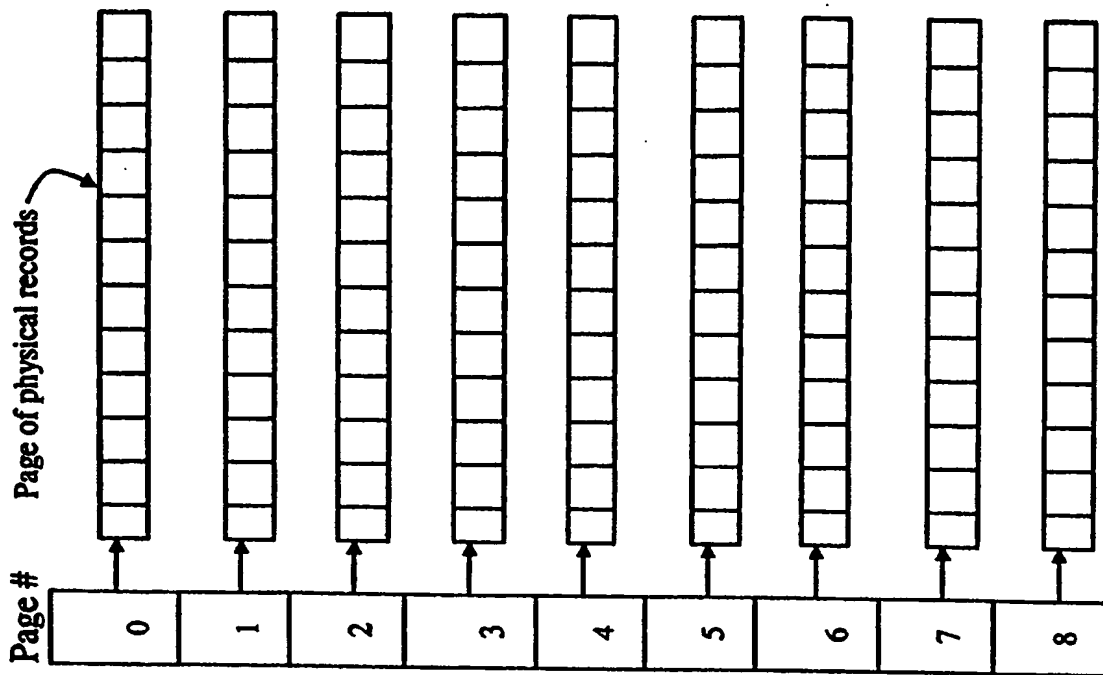


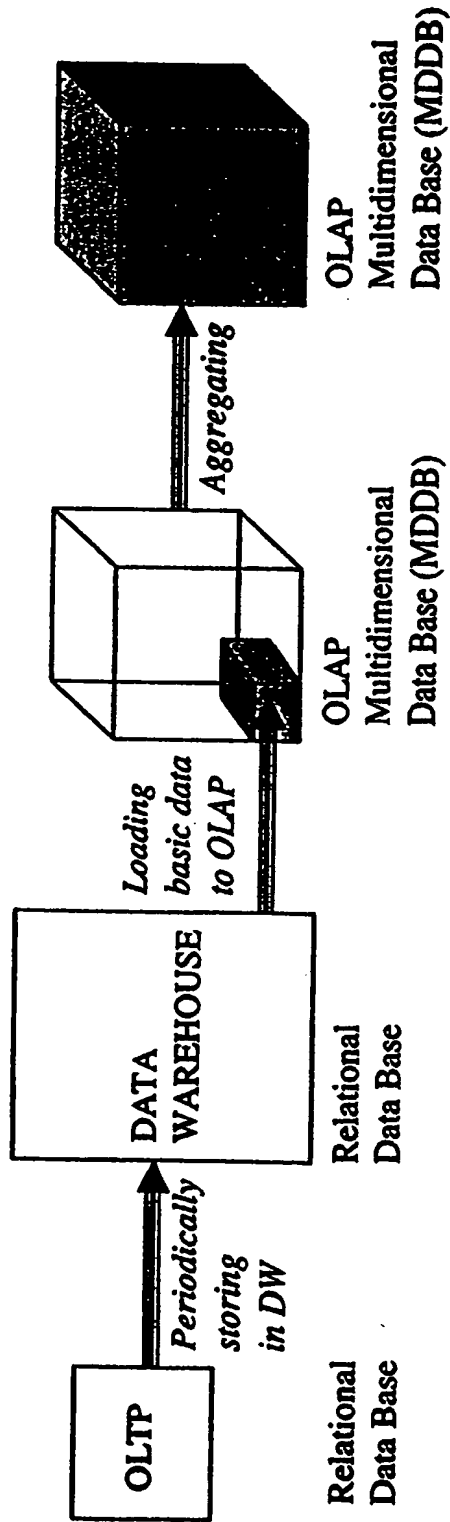
Fig. 2D  
DDIAD A DT

Array structure of a multidimensional variable

| D0   |      |   |   |   |   |
|------|------|---|---|---|---|
| 0    | 1    | 2 | 3 | 4 | 5 |
| D1=0 |      |   |   |   |   |
| D2=0 | D1=1 |   |   |   |   |
|      | D1=2 |   |   |   |   |
|      | D1=0 |   |   |   |   |
|      | D1=1 |   |   |   |   |
| D2=1 | D1=2 |   |   |   |   |
|      | D1=0 |   |   |   |   |
|      | D1=1 |   |   |   |   |
| D2=2 | D1=2 |   |   |   |   |
|      | D1=0 |   |   |   |   |
|      | D1=1 |   |   |   |   |
| D2=3 | D1=2 |   |   |   |   |
|      | D1=0 |   |   |   |   |
|      | D1=1 |   |   |   |   |
| D2=3 | D1=2 |   |   |   |   |
|      | D1=0 |   |   |   |   |
|      | D1=1 |   |   |   |   |
| D2=3 | D1=2 |   |   |   |   |

Fig. 2C

6/49



**Fig. 3A**  
**(PRIOR ART)**

7/49

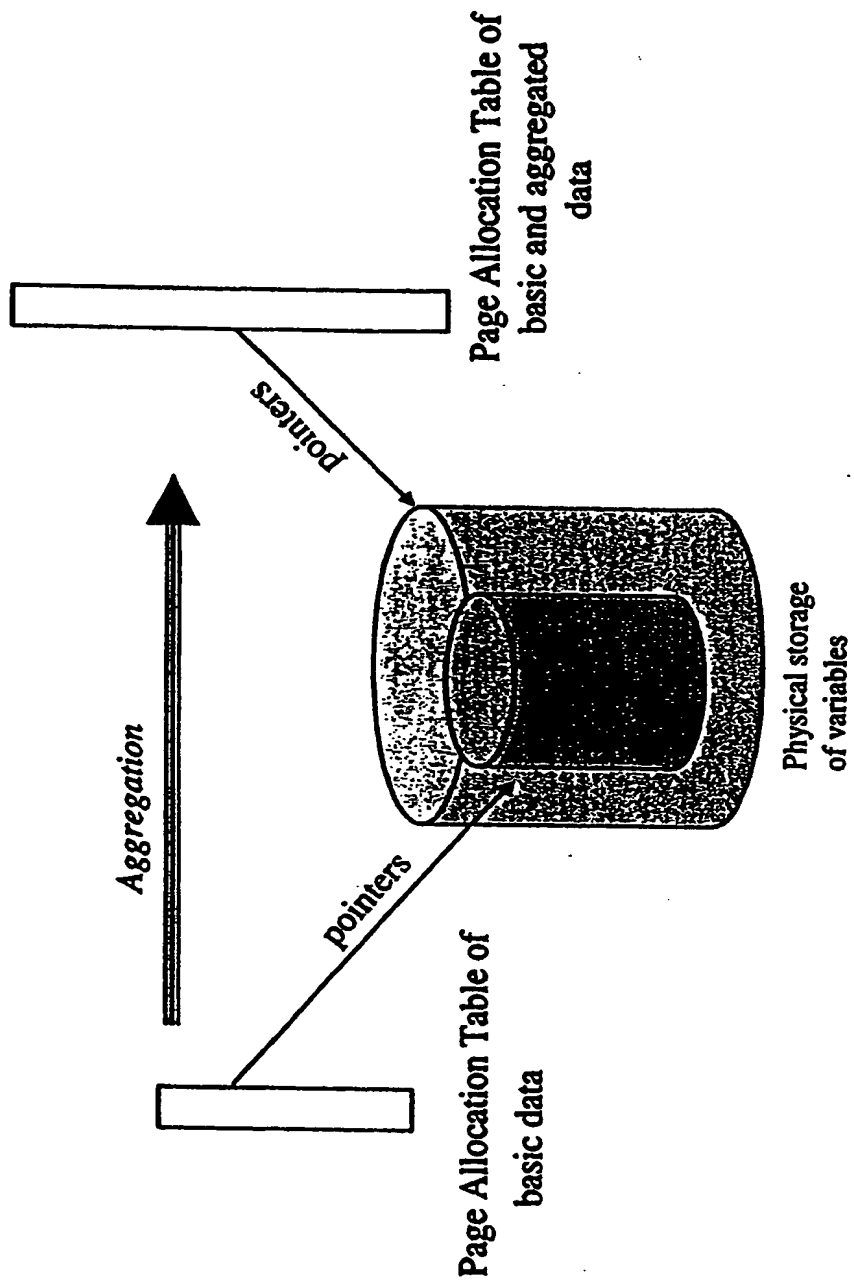
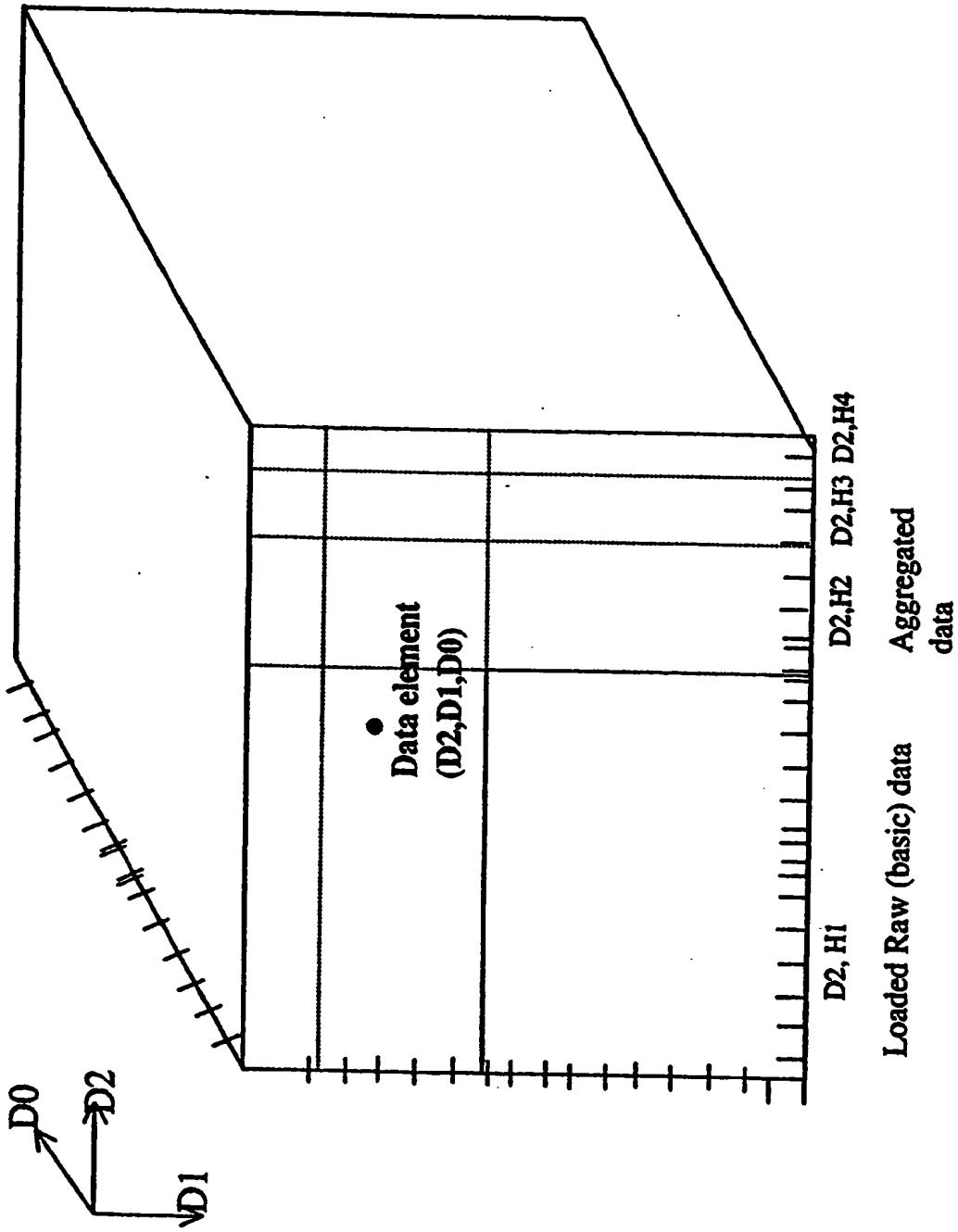


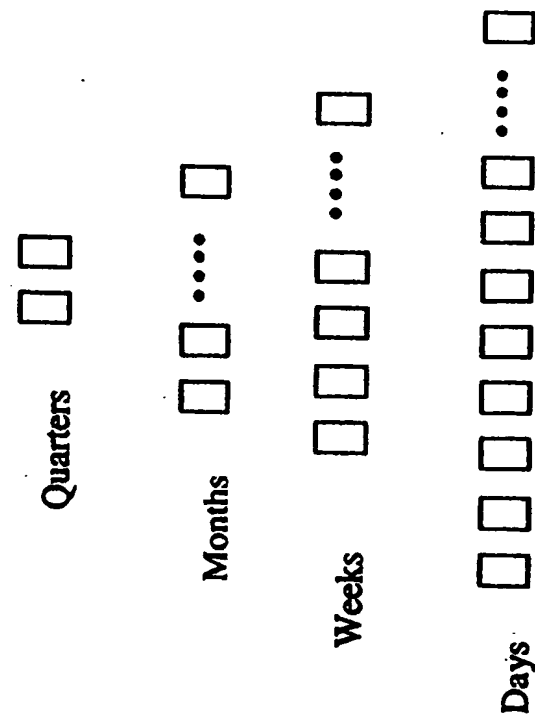
Fig. 3B  
(PRIOR ART)

8/49



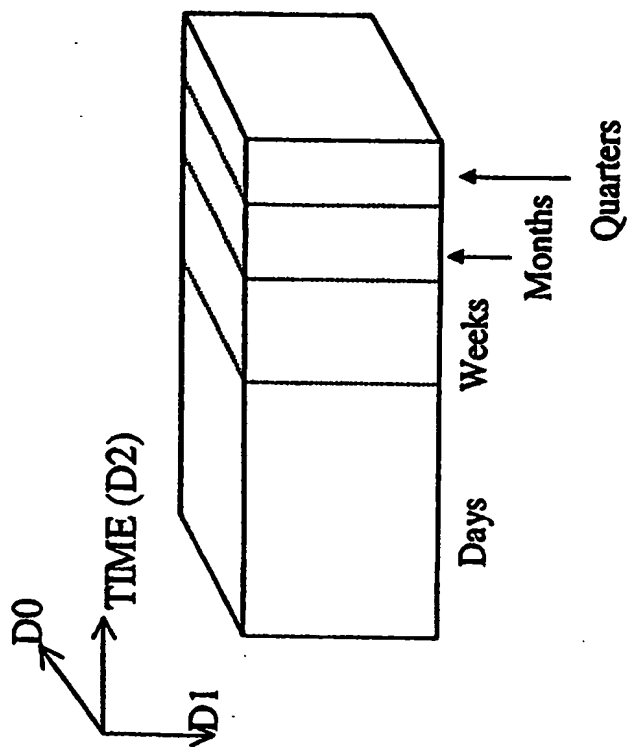
**Fig. 3C1**  
**(PRIOR ART)**





Hierarchy of TIME dimension

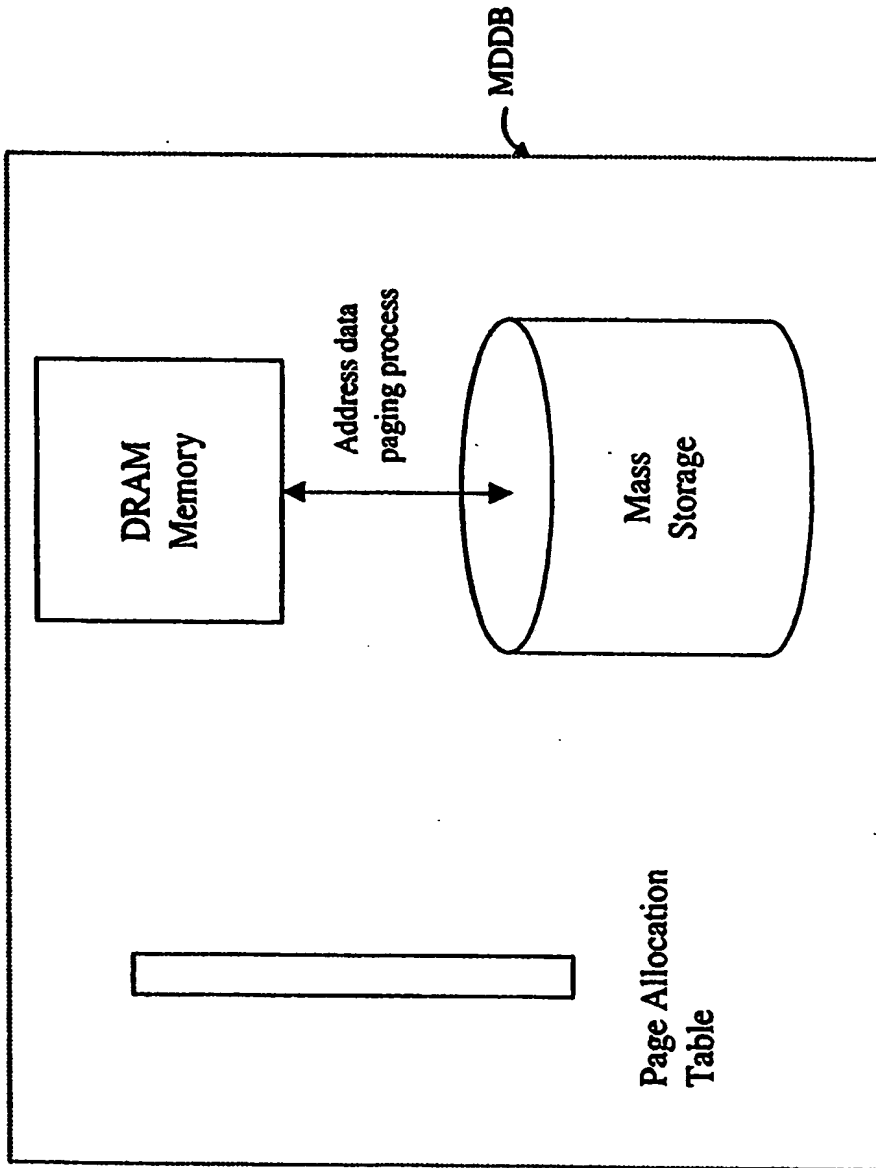
Fig. 3C2  
(PRIOR ART)



Spatial occupancy of TIME hierarchy

Fig. 3C3  
(PRIOR ART)

10/49



**Fig. 4**  
**(PRIOR ART)**

11/49

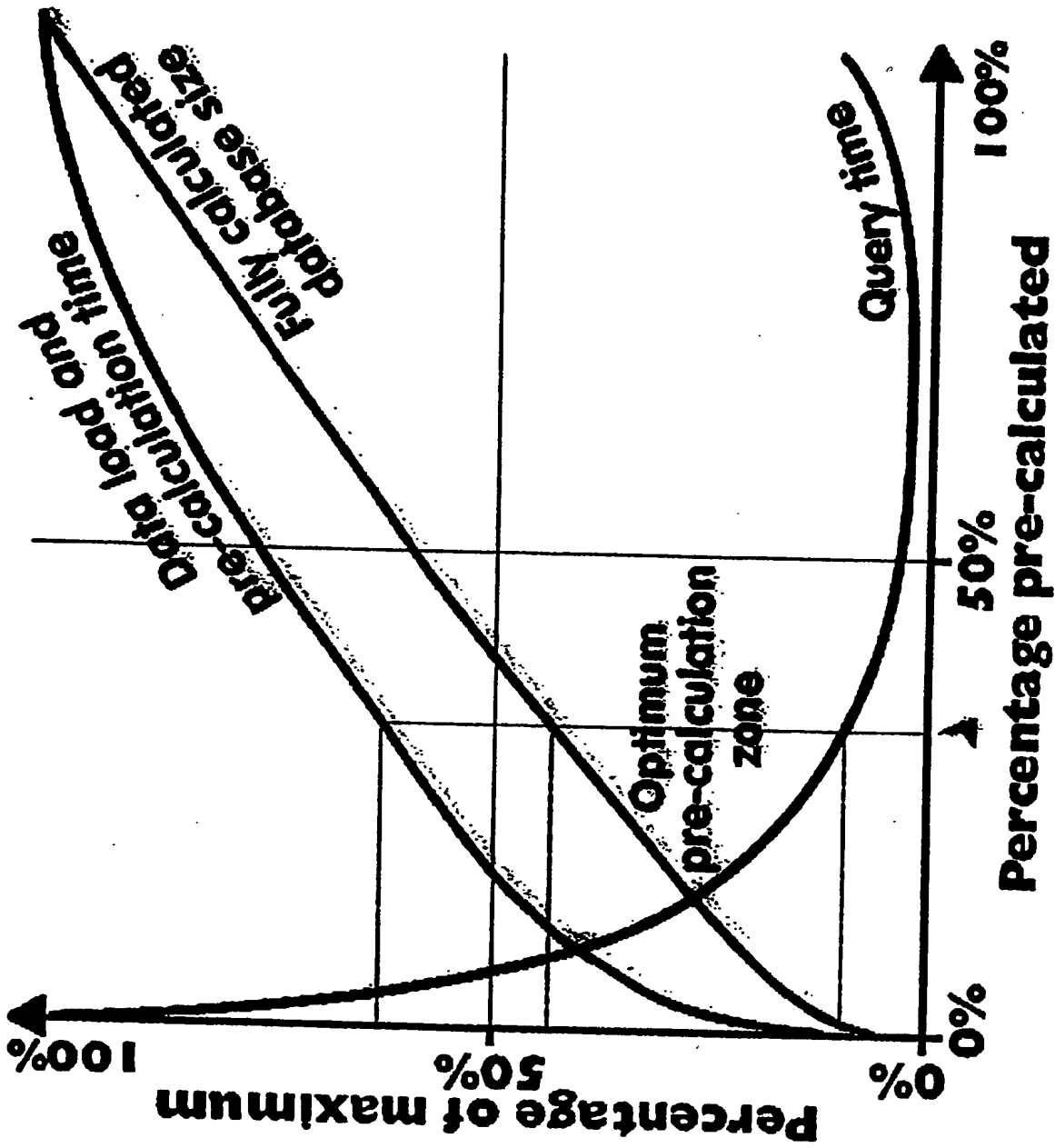


Fig. 5  
(PRIOR ART)

12/49

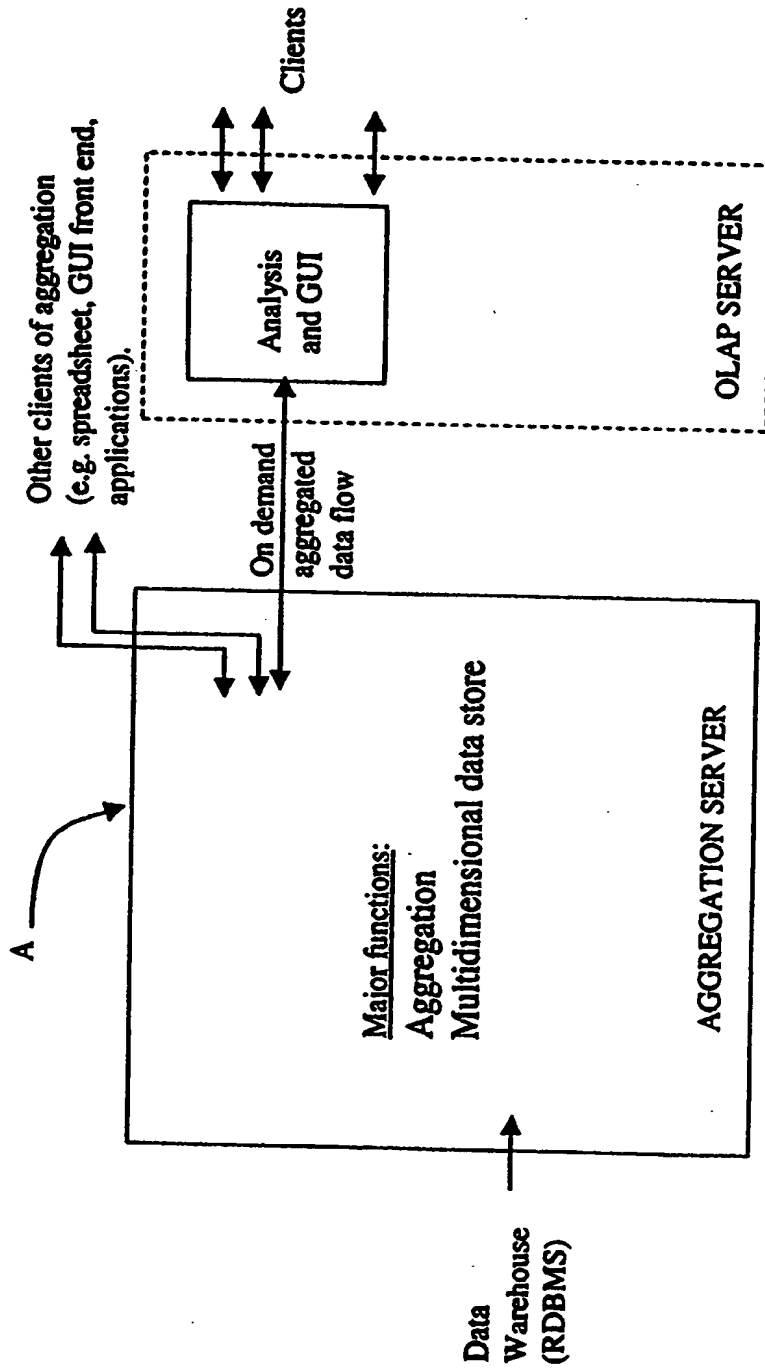


Fig. 6A

13/49

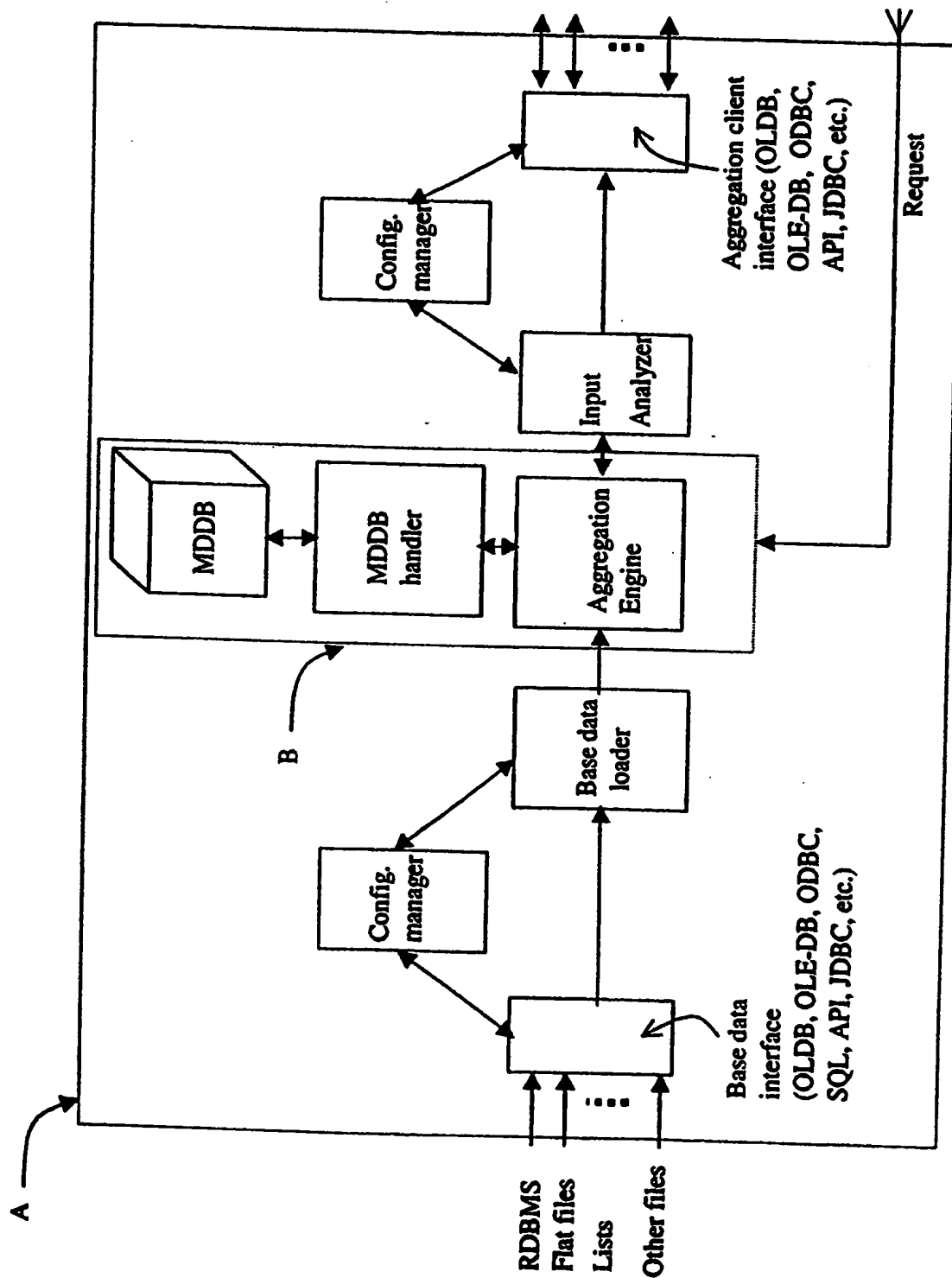


Fig. 6B

14/49

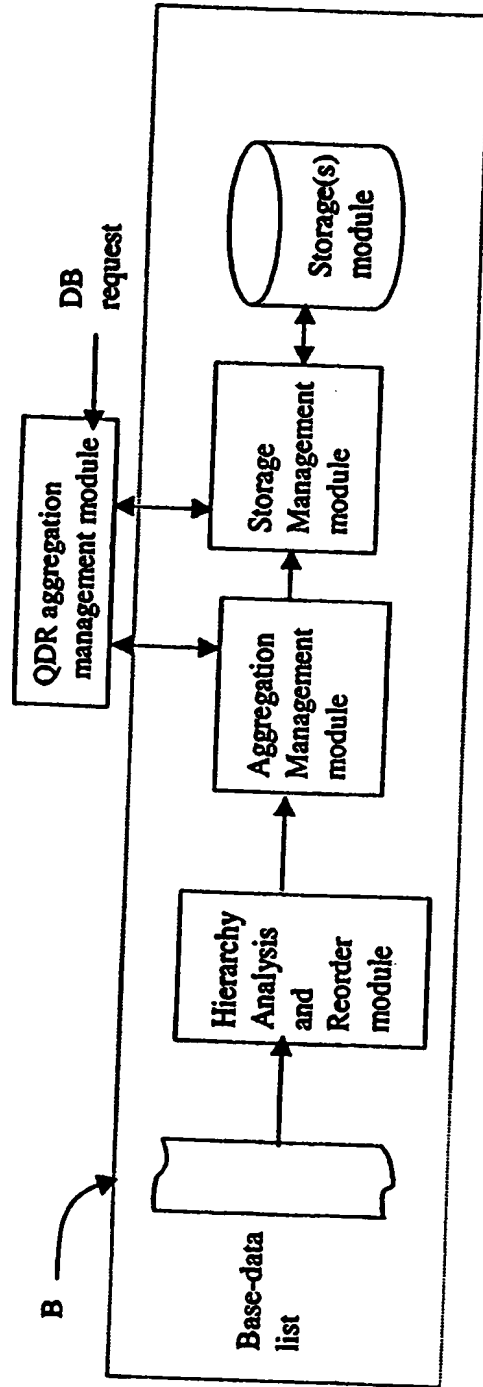


Fig. 6C

15/49

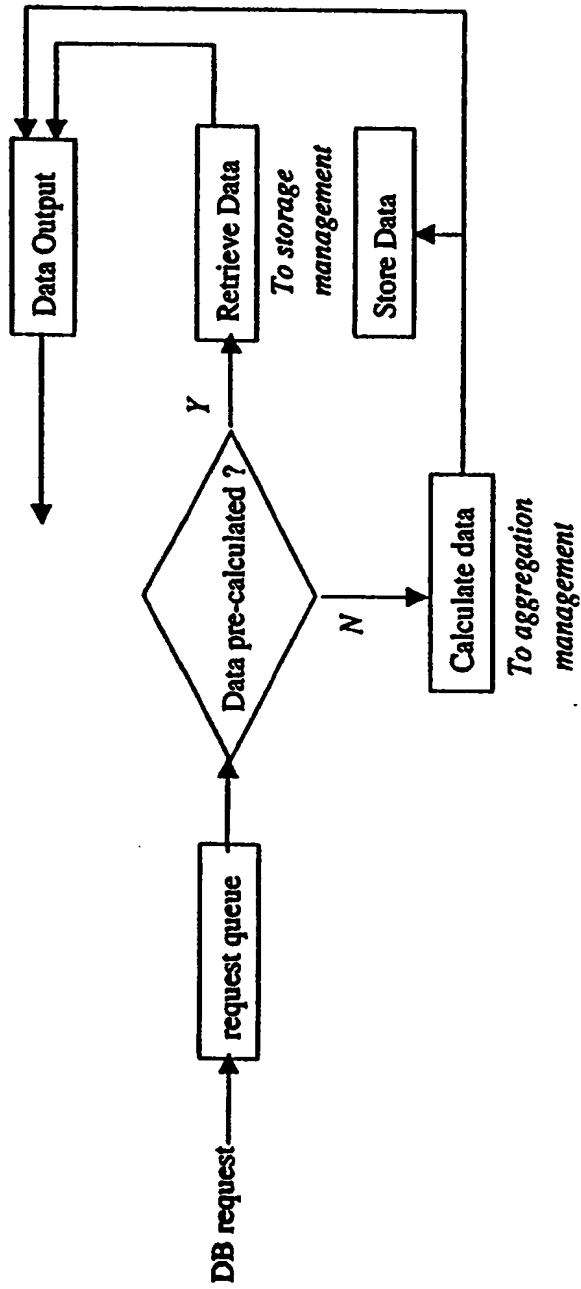


Fig. 6D

16/49

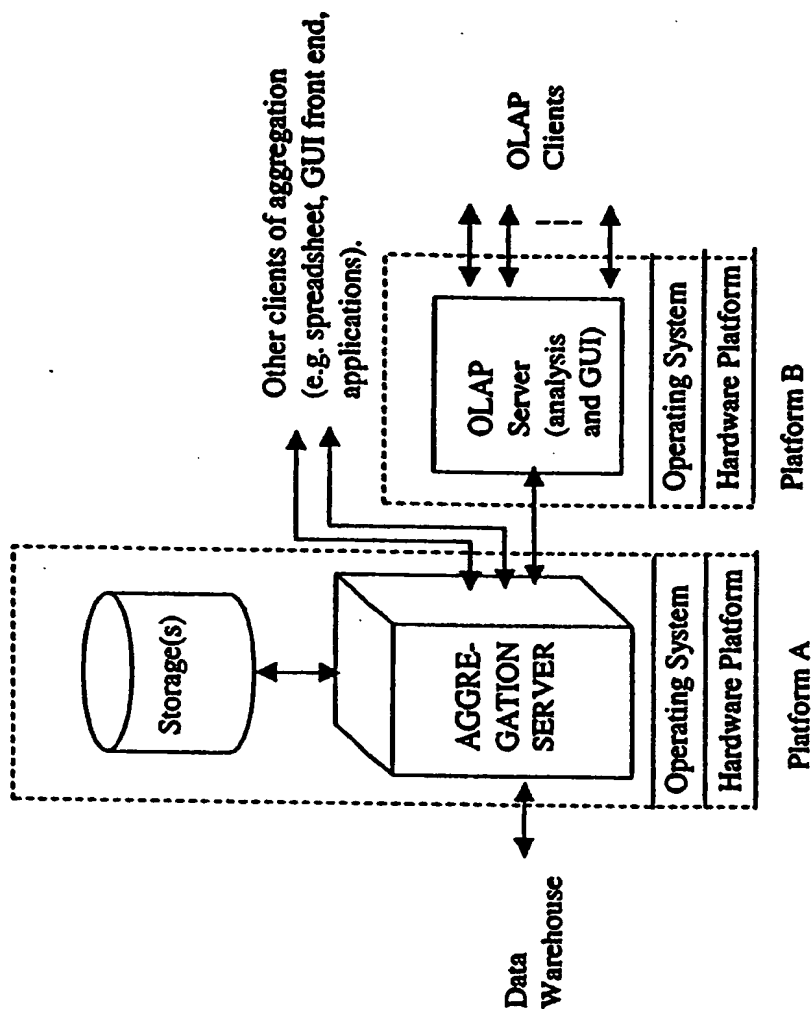


Fig. 7A



17/49

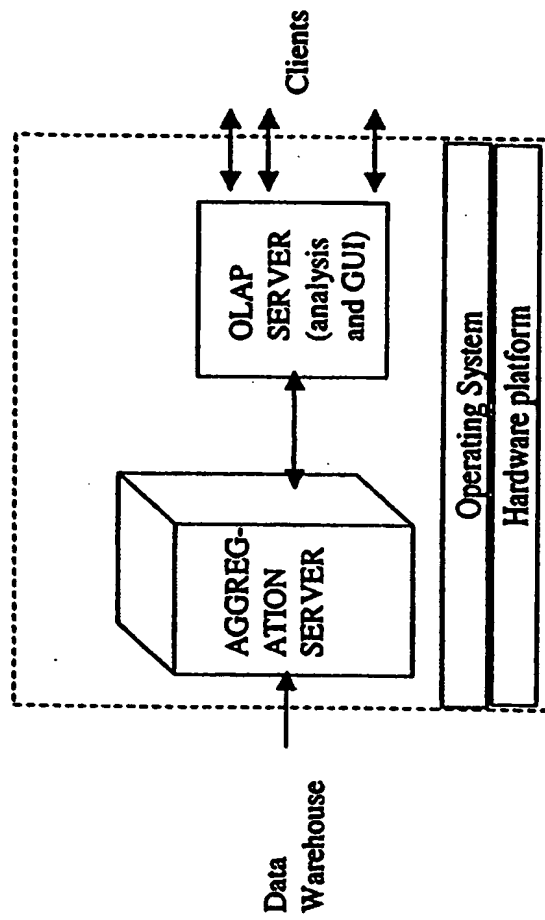


Fig. 7B

18/49

|    | Nbr of Dim. | Nbr. of atomic data values | Leaf node density % | Number of values in cube after roll-up | Oracle EXPRESS v. 6.2 | Implementation of current invention |
|----|-------------|----------------------------|---------------------|--|-----------------------|-------------------------------------|
| D1 | 6           | 302 M                      | 9                   | 427 M                                  | 16 h                  | 15 m                                |
| D2 | 4           | 414 M                      | 1.27                | 969 M                                  | 50 m                  | 5 m                                 |
| D3 | 5           | 14,499 M                   | 0.03                | 63,954 M                               | 31 h                  | 1h 23m                              |
| D4 | 6           | 623,494 M                  | $8 \cdot 10^{-4}$   | 7,930 G                                | Exceeds 48h           | 2h 20m                              |
| D5 | 6           | 243,000 G                  | $10^{-3}$           | 1,160,000 G                            | 22 h                  | 4 m                                 |
| D6 | 4           | 7 M                        | defined as 100      | 19 M                                   | 15 m                  | 1 m                                 |

Fig. 8A

19/49

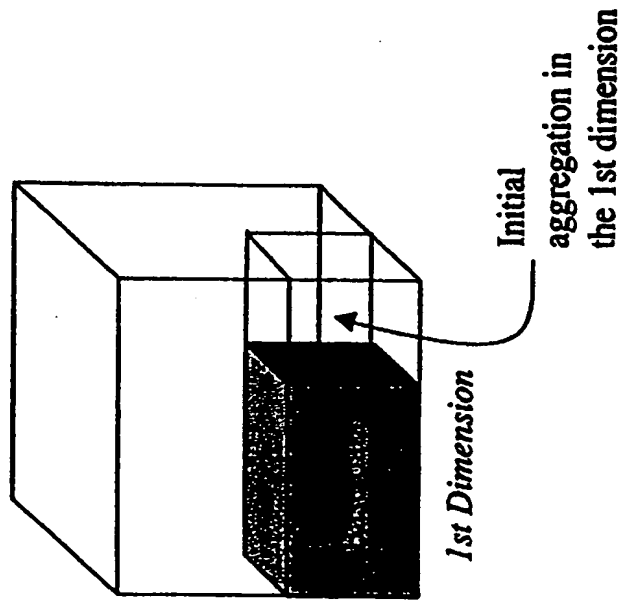


Fig. 9A

20/49

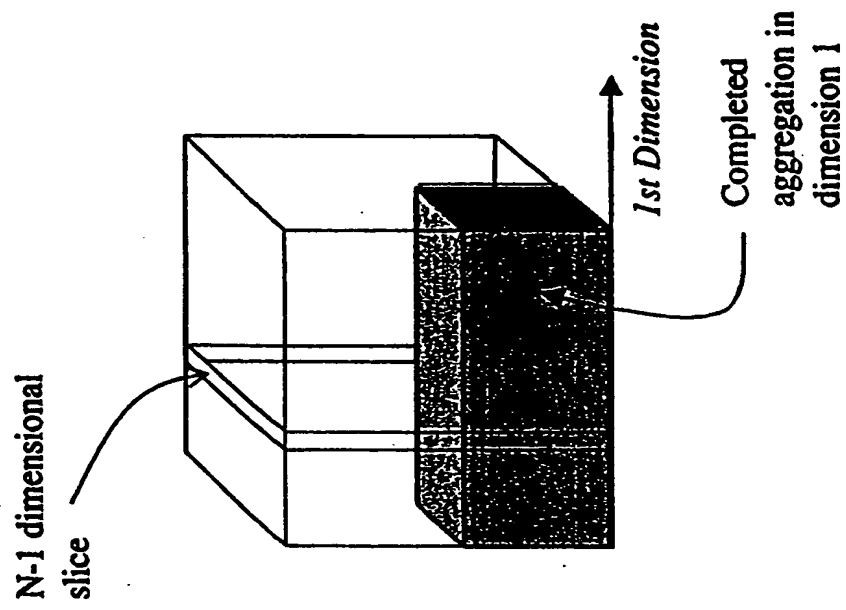
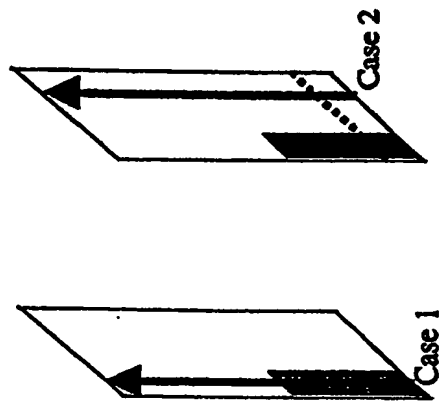


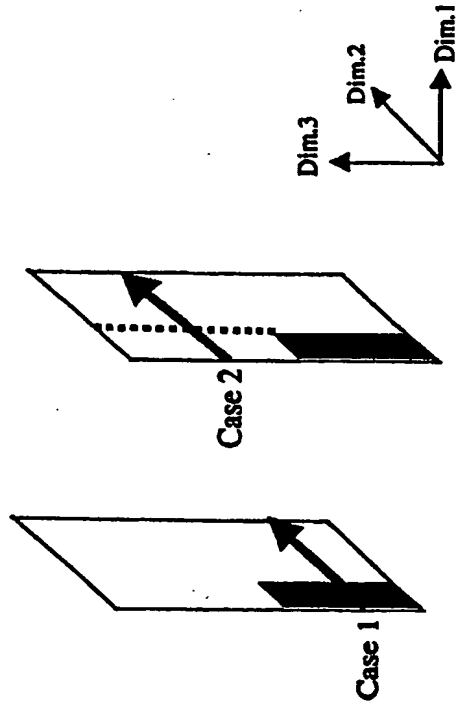
Fig. 9B

21/49



b. Directed aggregation in dimension 3, cases 1 and 2.

Fig. 9C2



a. Directed aggregation in dimension 2, cases 1 and 2.

Fig. 9C1

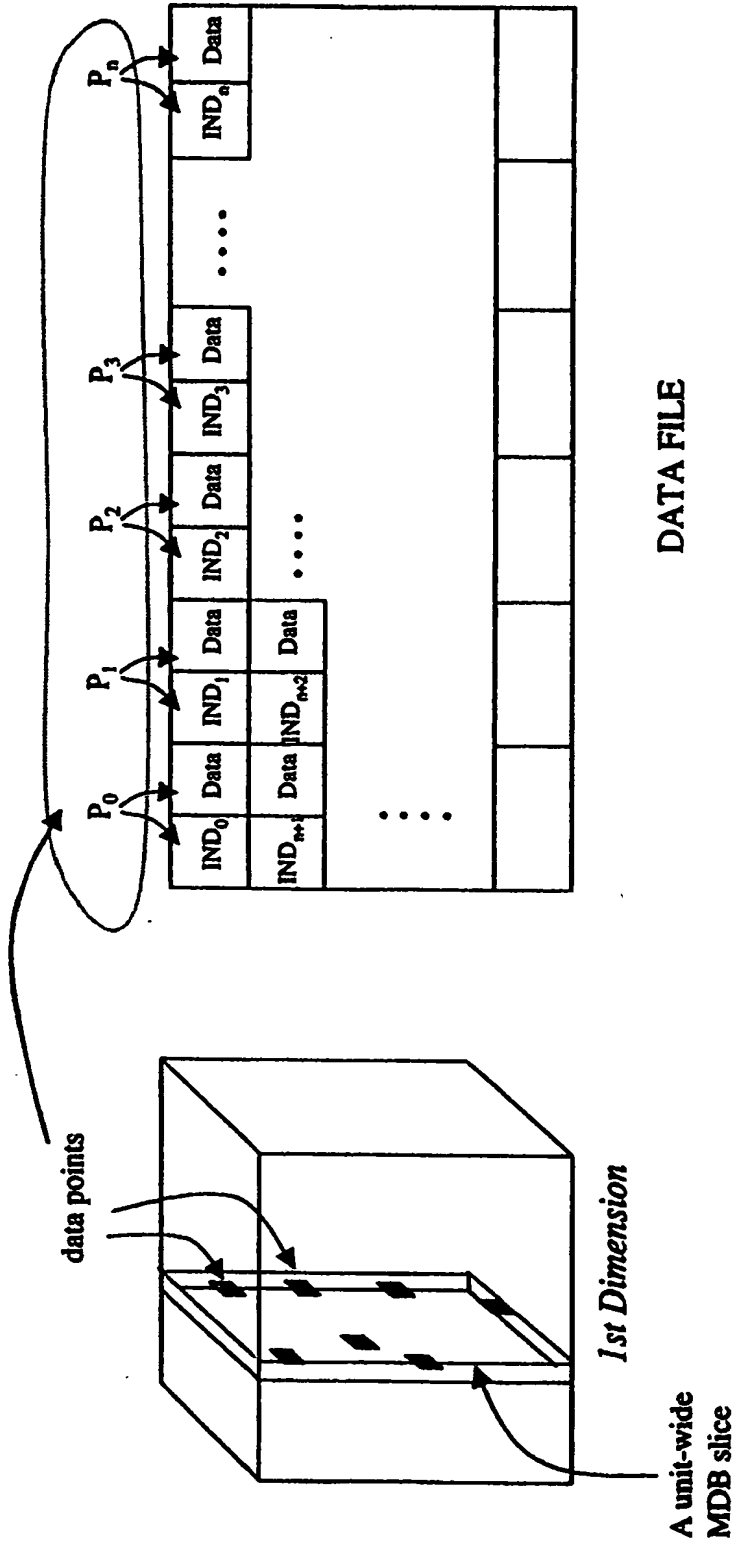
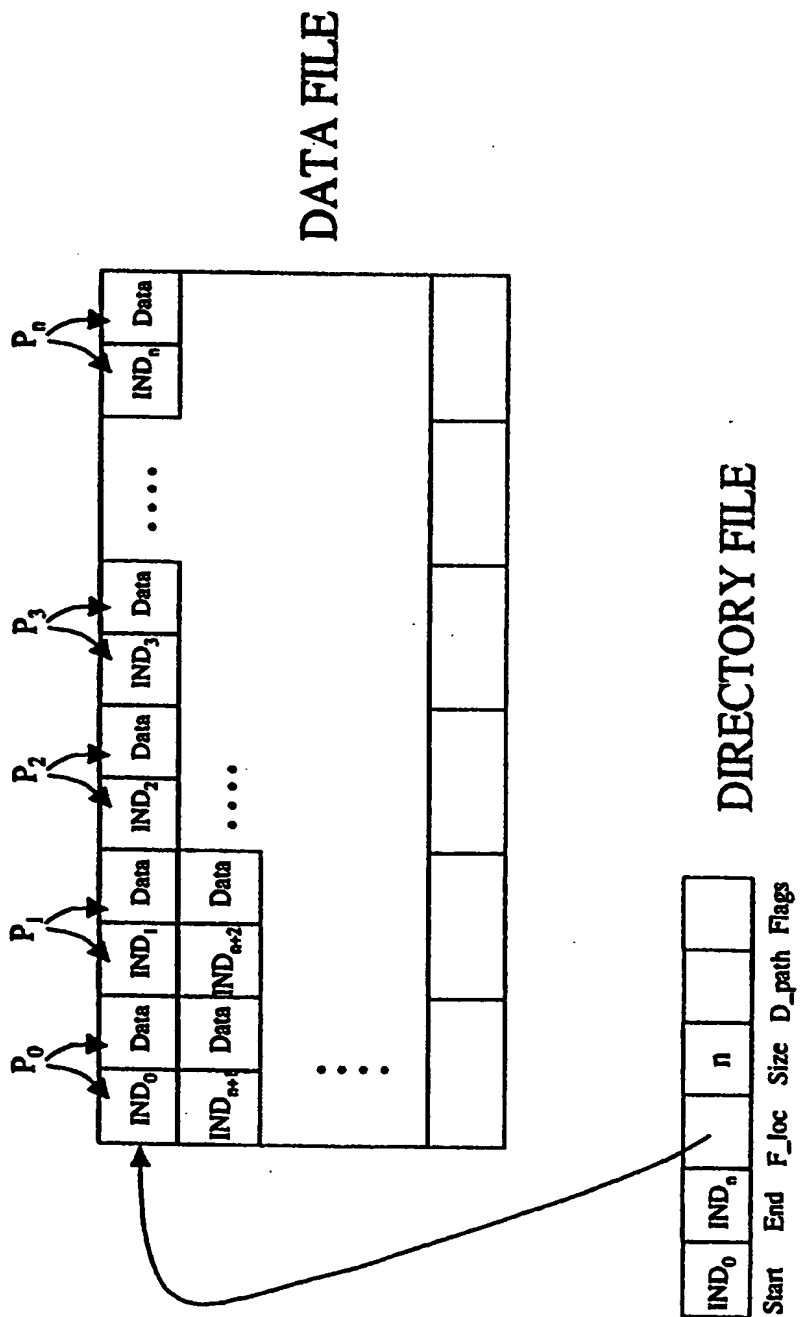
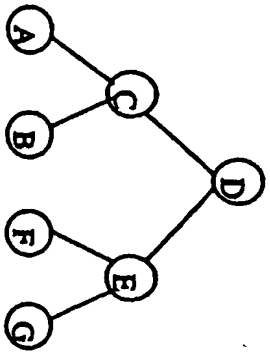


Fig. 10A

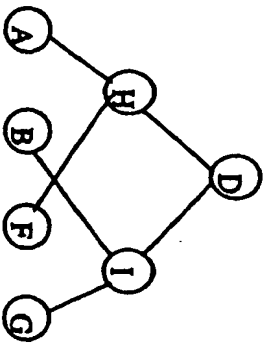


**Fig. 10B**

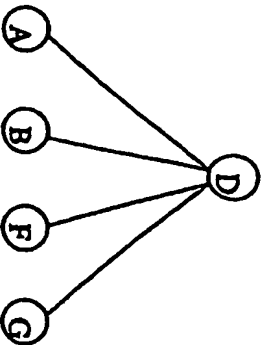
24/49



Struct. 1



Struct. 2



Struct. 3

Fig. 11A

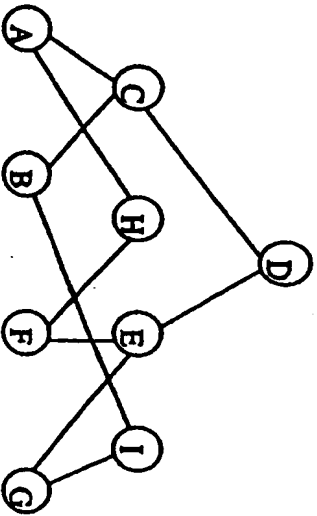


Fig. 11B



25/49

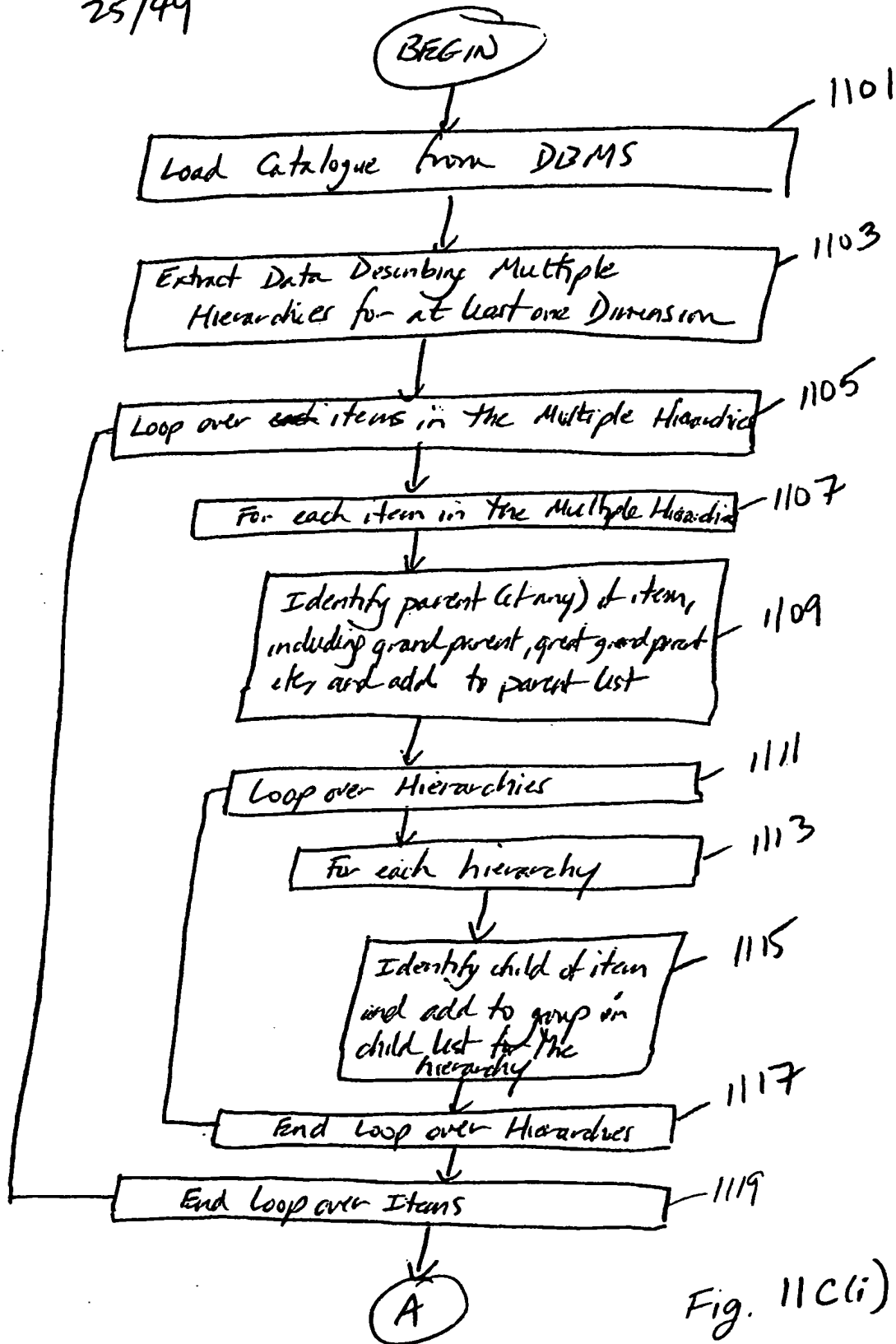


Fig. 11C(ii)

26/49

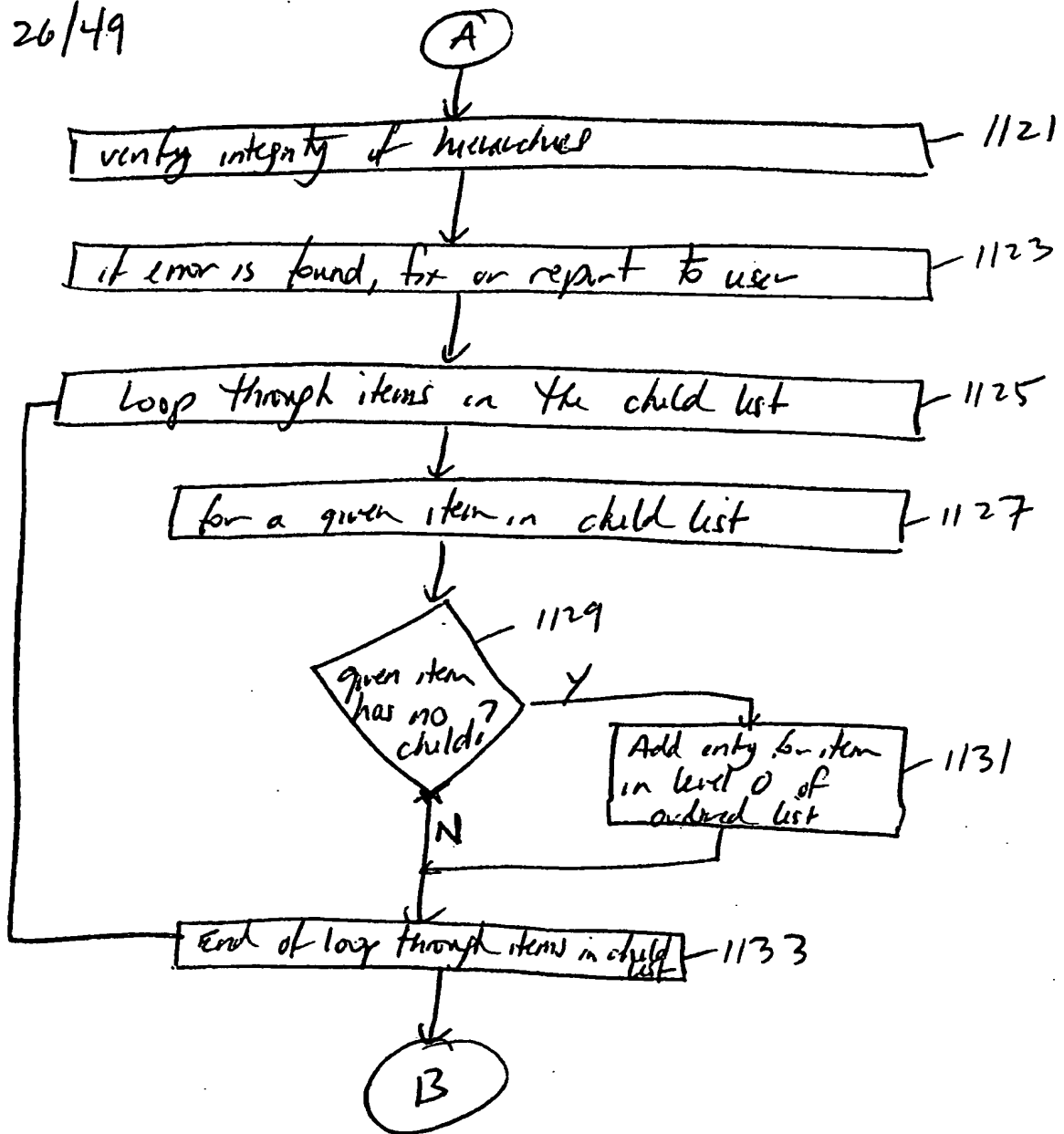


Fig. 11C(ii)

27/49

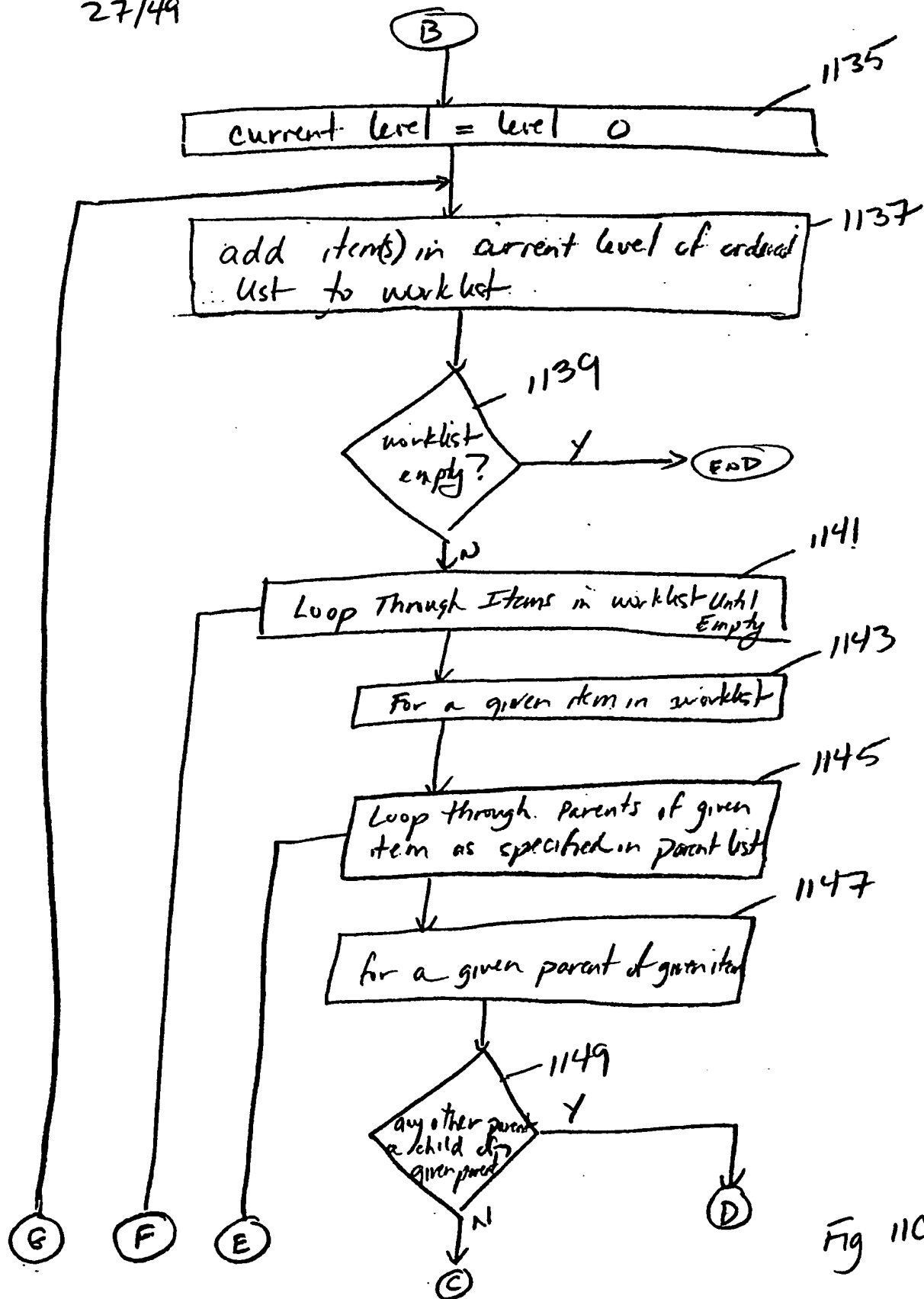


Fig 11C(iii)

28/49

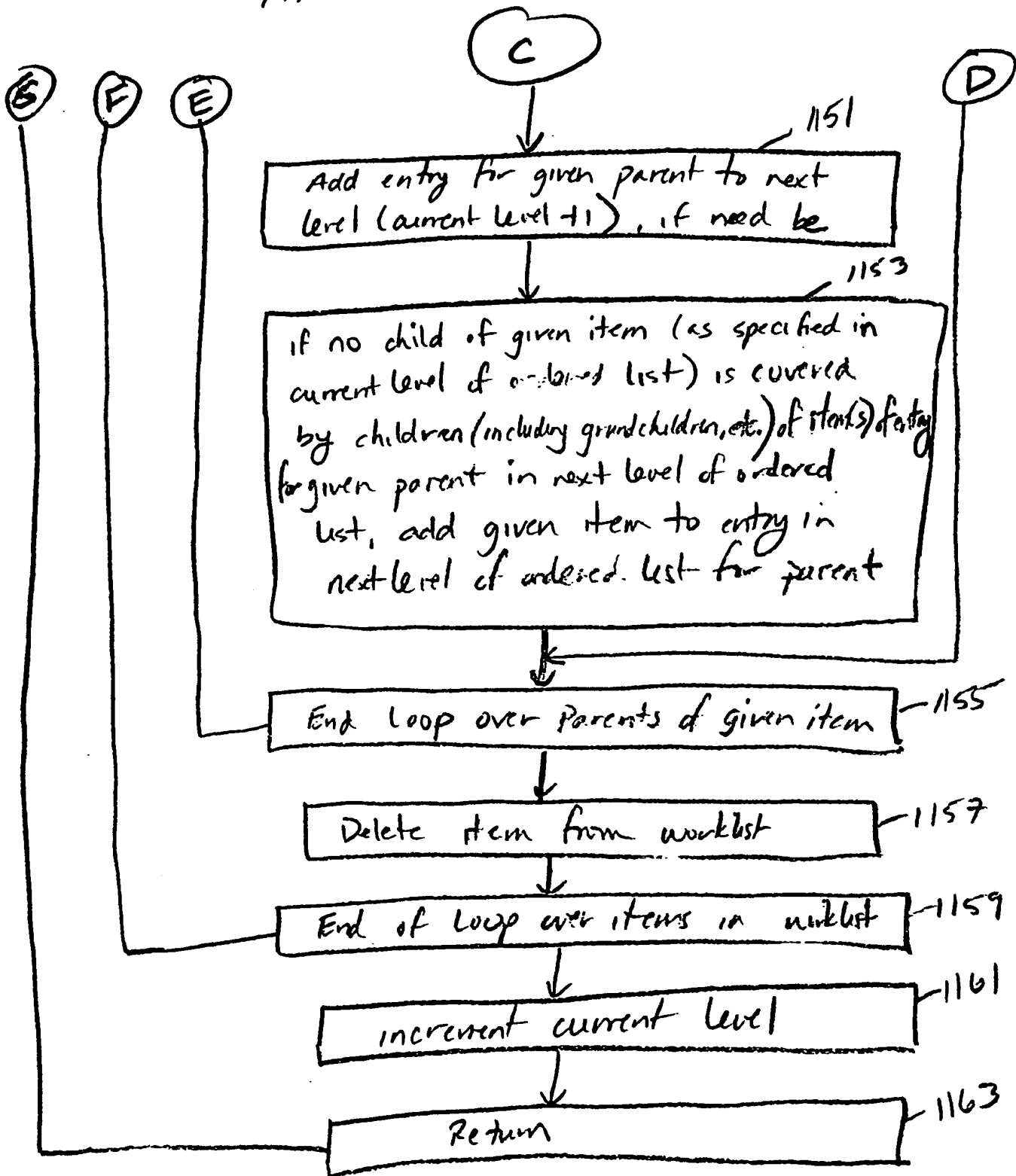


FIG. 11C(iv)

Parent List

29/49

Child List

| Item | Parent(s) |
|------|-----------|
| A    | C, H, D   |
| B    | C, I, D   |
| F    | E, H, D   |
| G    | E, I, D   |
| C    | D         |
| H    | D         |
| E    | D         |
| I    | D         |
| D    | —         |

FIG 11C(iv)

Ordered List

| Item | Child(ren)                   |
|------|------------------------------|
| A    | —                            |
| B    | —                            |
| F    | —                            |
| G    | —                            |
| C    | <A, B>                       |
| H    | <F, G>                       |
| E    | <A, F>                       |
| I    | <B, G>                       |
| D    | <A, B, F, G>, <H, I>, <C, E> |

Fig 11C(vi)

Level 0

| Item | Child(ren) |
|------|------------|
| A    | —          |
| B    | —          |
| F    | —          |
| G    | —          |

FIG. 11C(vii)

Level 1

| Item | Child(ren) |
|------|------------|
| C    | A, B       |
| H    | A, F       |
| I    | B, G       |
| E    | F, G       |

FIG. 11C(viii)

Level 2

| Item | Child(ren) |
|------|------------|
| D    | C, E       |

FIG. 11C(ix)

|                                    |
|------------------------------------|
| Aggregation Engine                 |
| Loading and Indexing<br>Module     |
| Hierarchy Transformation<br>Module |

**Fig. 12**

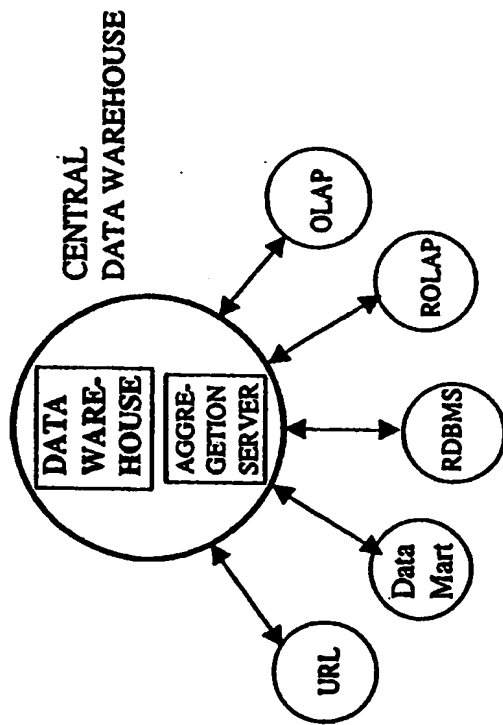
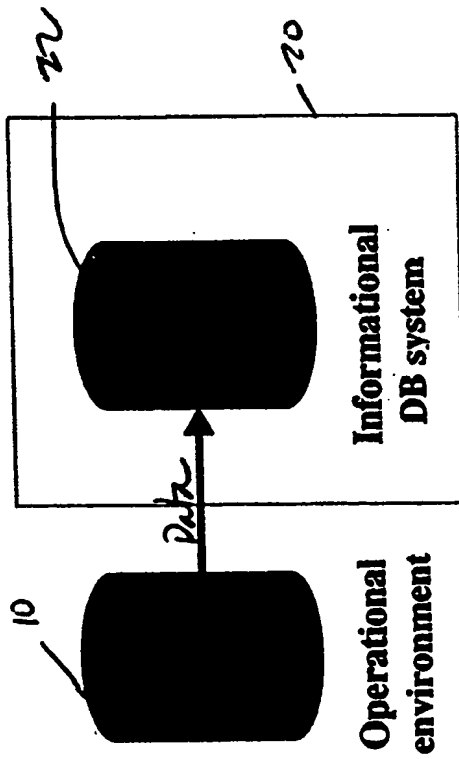


Fig. 13

67/1E



|                        |                                  |
|------------------------|----------------------------------|
| Continuous data        | Snap-shots                       |
| On-line processed data | Extract processing (copied data) |
| Normalized data        | Data warehouse                   |
|                        | Data marts                       |
|                        | OLAP                             |
|                        | Data mining                      |
|                        | EC-enabled Web <i>servers</i>    |
|                        | EDI B-2-B Exchange               |
|                        | De-normalized data               |

FIG. 14 (PRIOR ART)

32/49



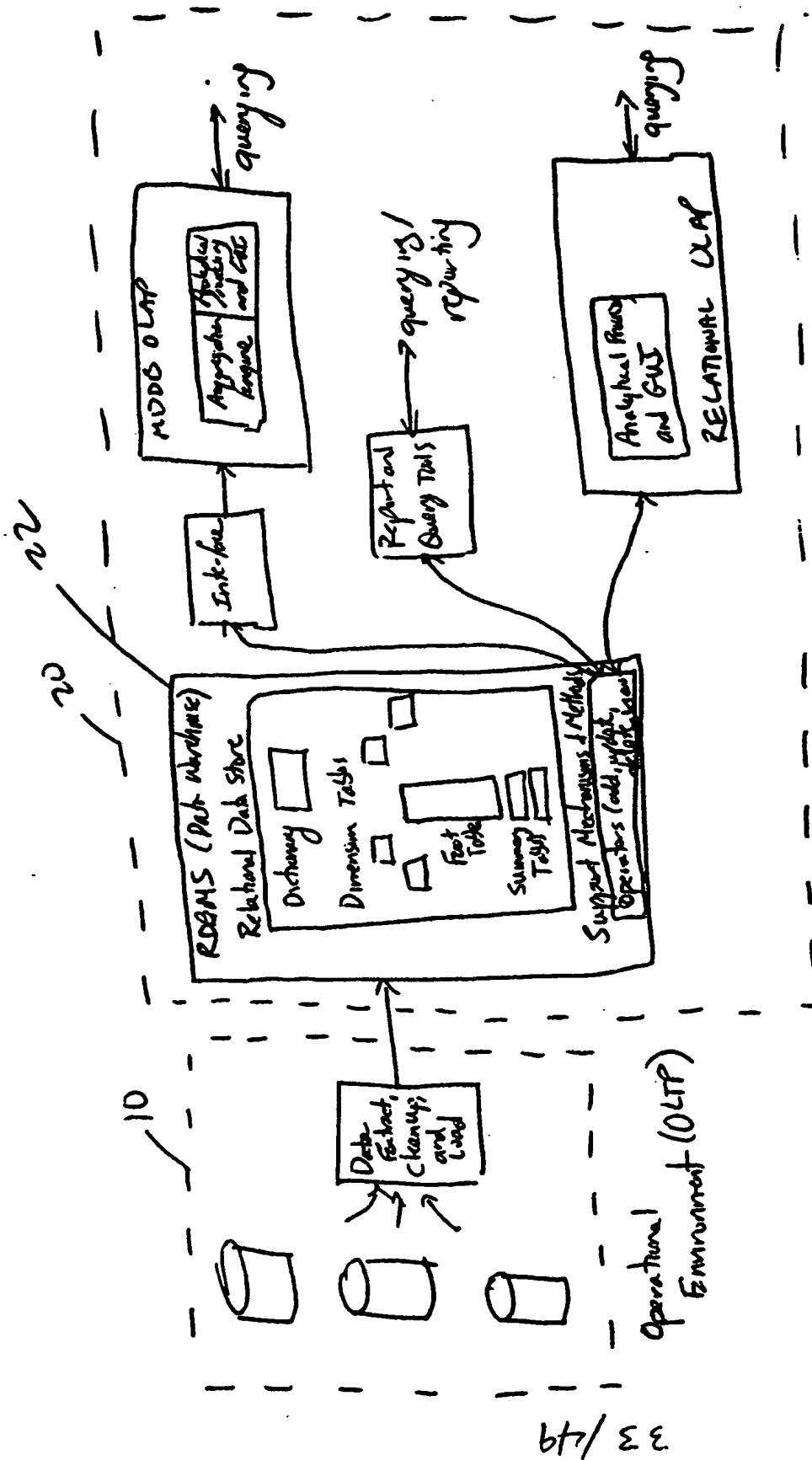


FIG. 15  
(Prior Art)

34/49

CELLAR

| Wine       | Year | Bottles |
|------------|------|---------|
| Chardonnay | 1996 | 4       |
| Fume Blanc | 1996 | 2       |
| Pinot Noir | 1993 | 3       |
| Zinfandel  | 1994 | 9       |

FIG. 16A

Restrict: *operator* :  
SELECT WINE, YEAR, BOTTLES  
FROM CELLAR  
WHERE YEAR > 1995;

Result:

| Wine       | Year | Bottles |
|------------|------|---------|
| Chardonnay | 1996 | 4       |
| Fume Blanc | 1996 | 2       |

FIG 16B

Project: *operator* :  
SELECT WINE, BOTTLES  
FROM CELLAR;

Result:

| Wine       | Bottles |
|------------|---------|
| Chardonnay | 4       |
| Fume Blanc | 2       |
| Pinot Noir | 3       |
| Zinfandel  | 9       |

FIG. 16C

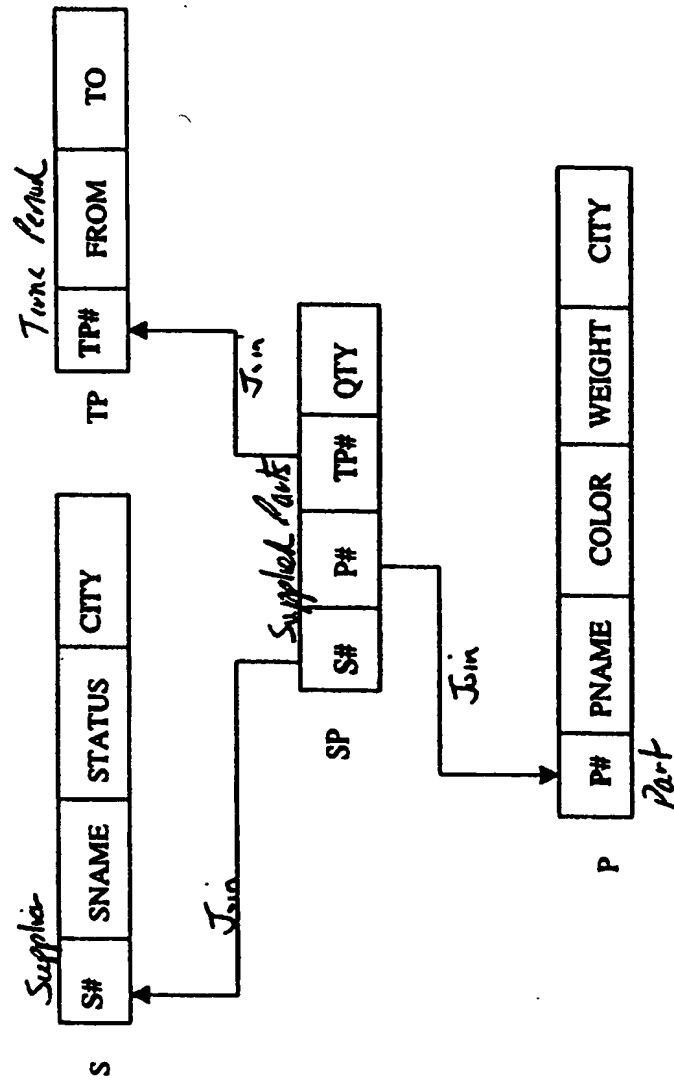


FIG. 17A

36/49

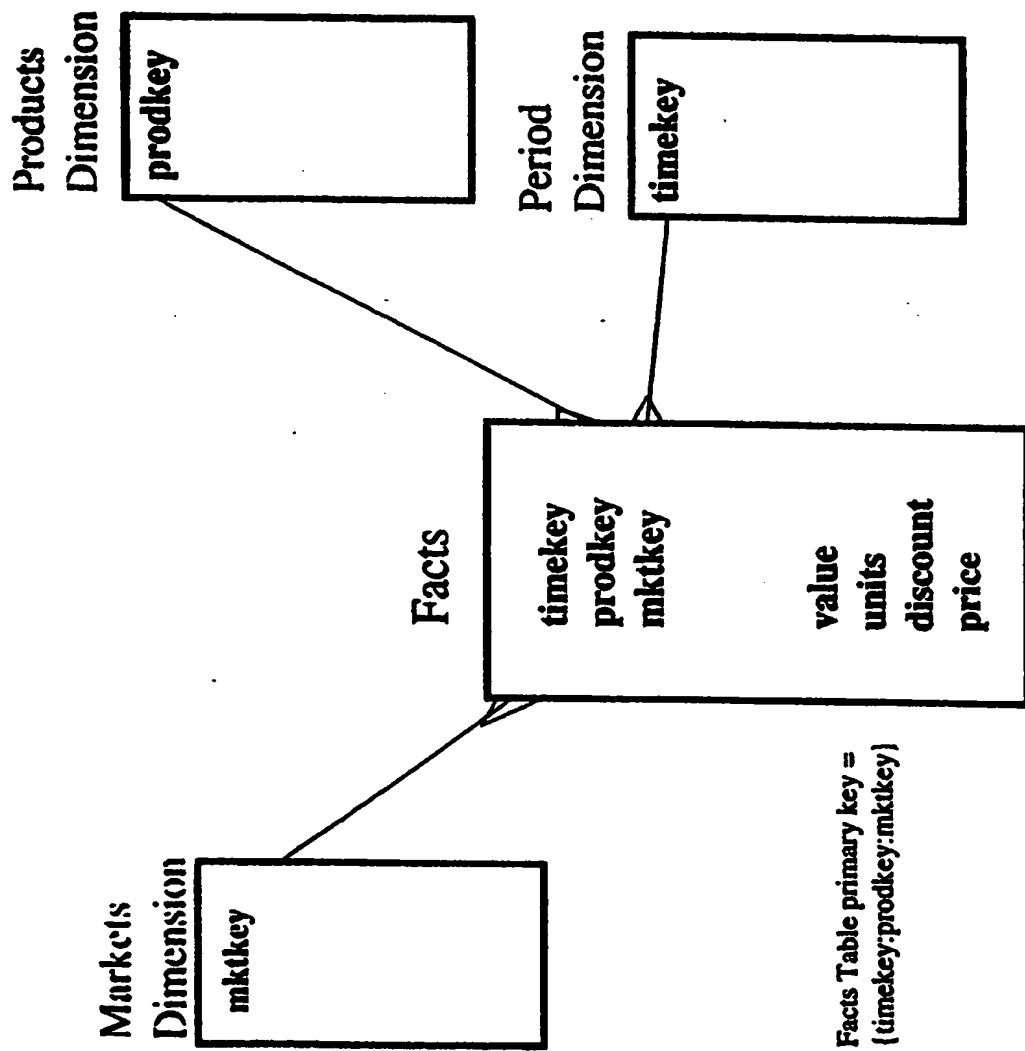


FIG. 18A

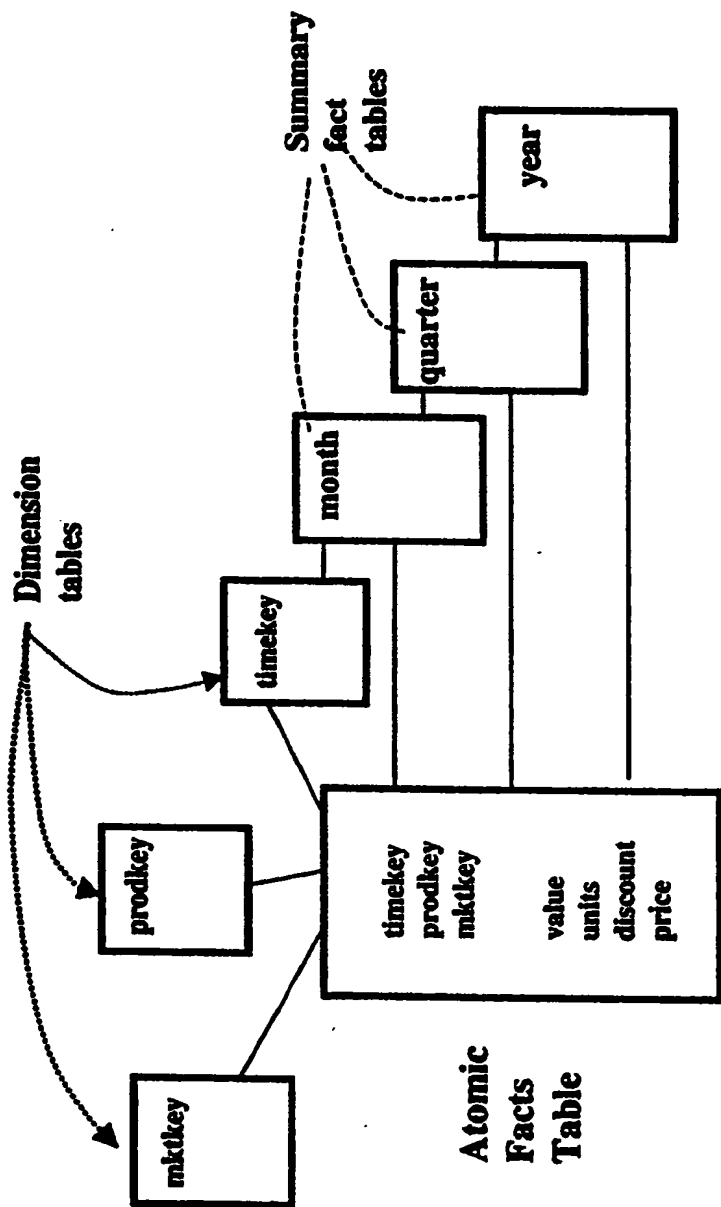


FIG. 18B

bh/tE

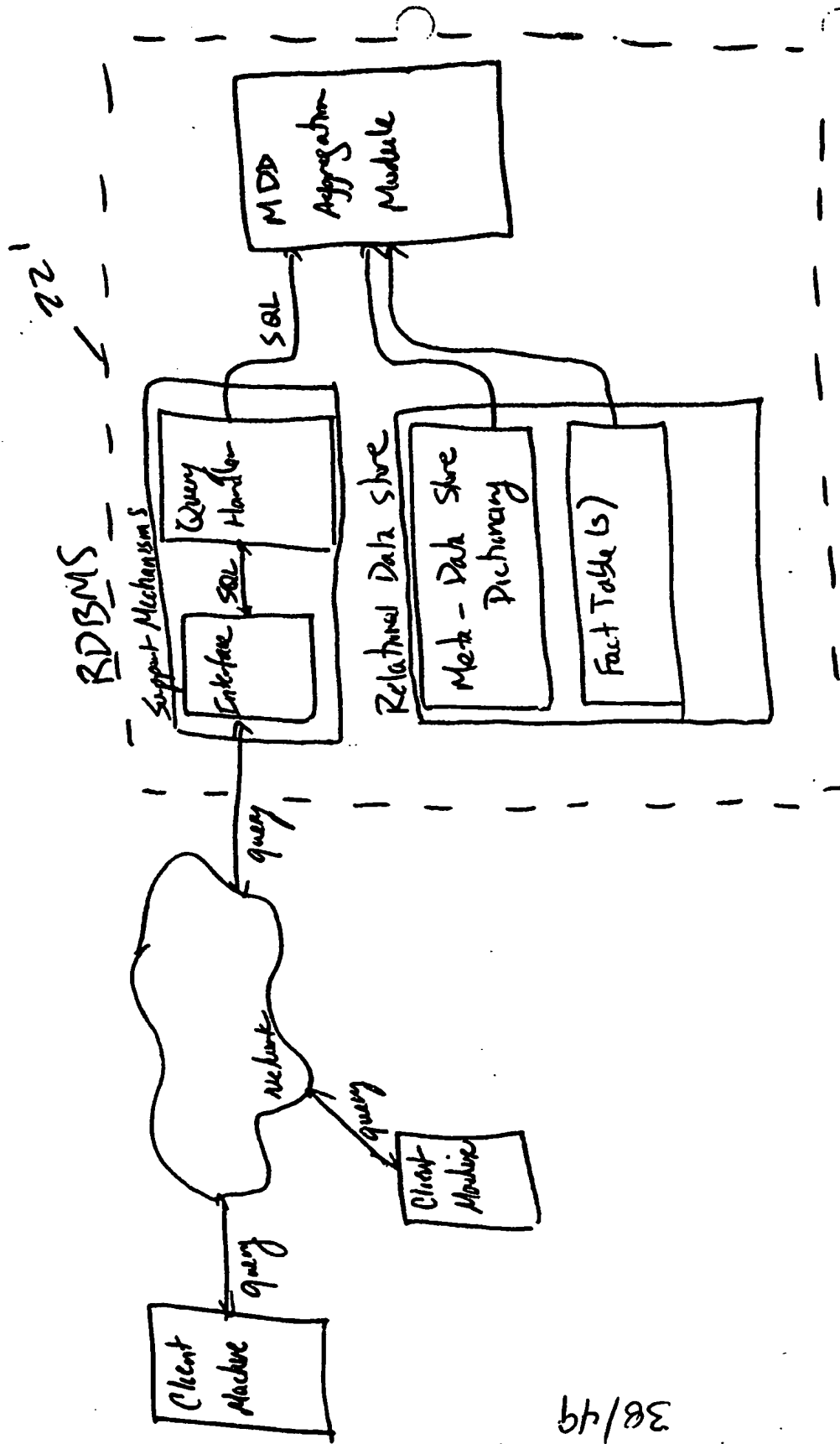


FIG. 19A

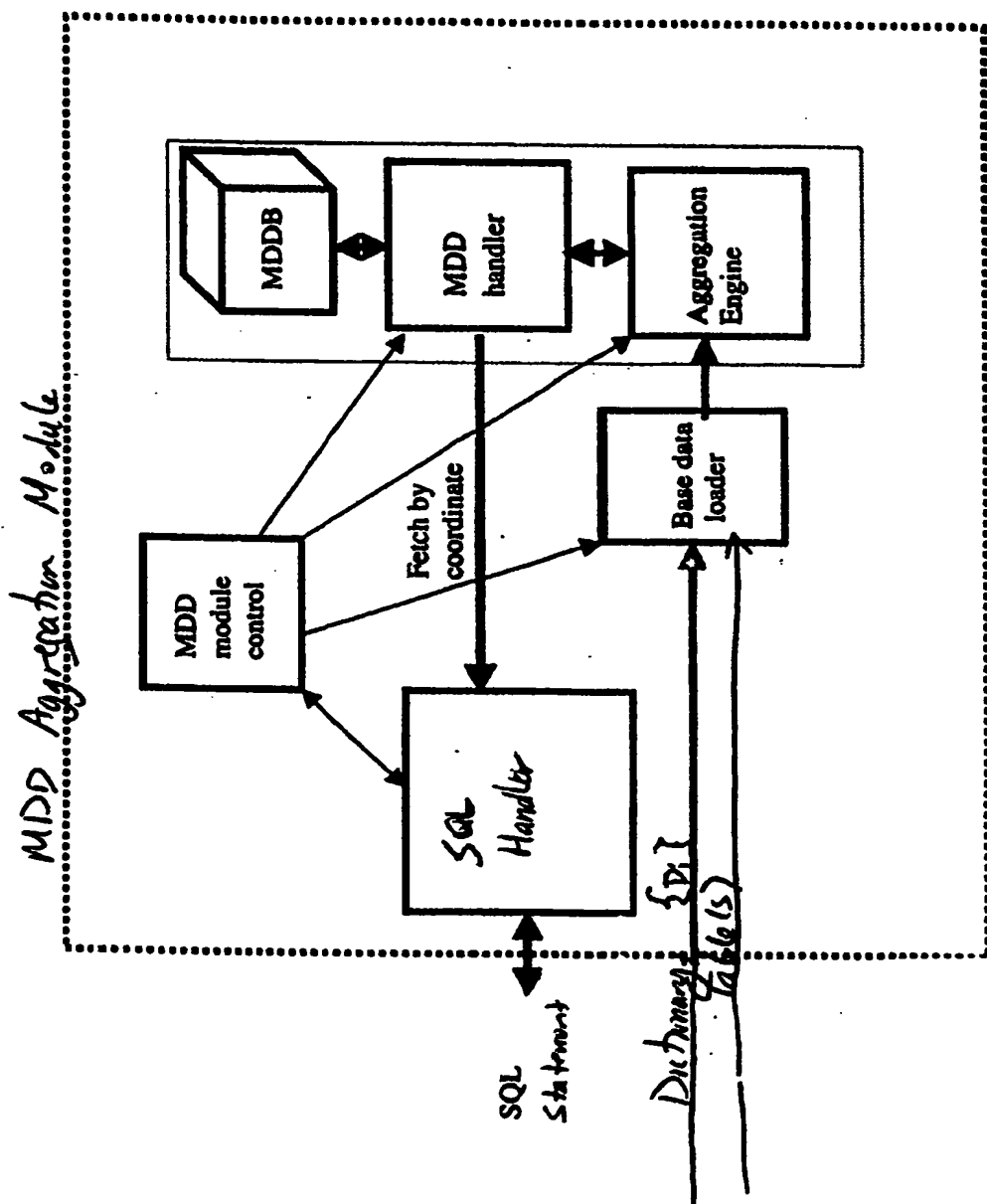


FIG. 193

40/49

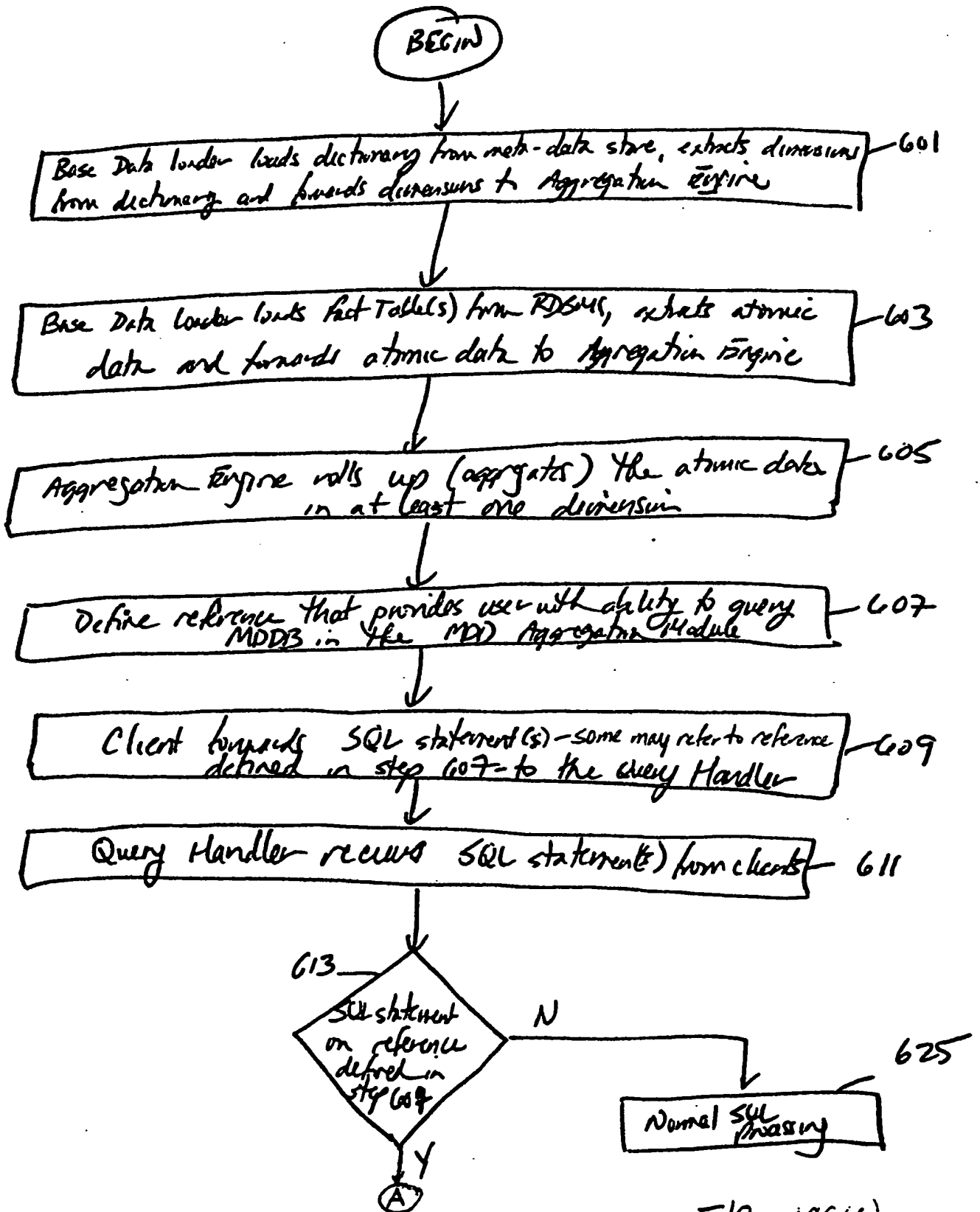


FIG. 19C(i)



41/49

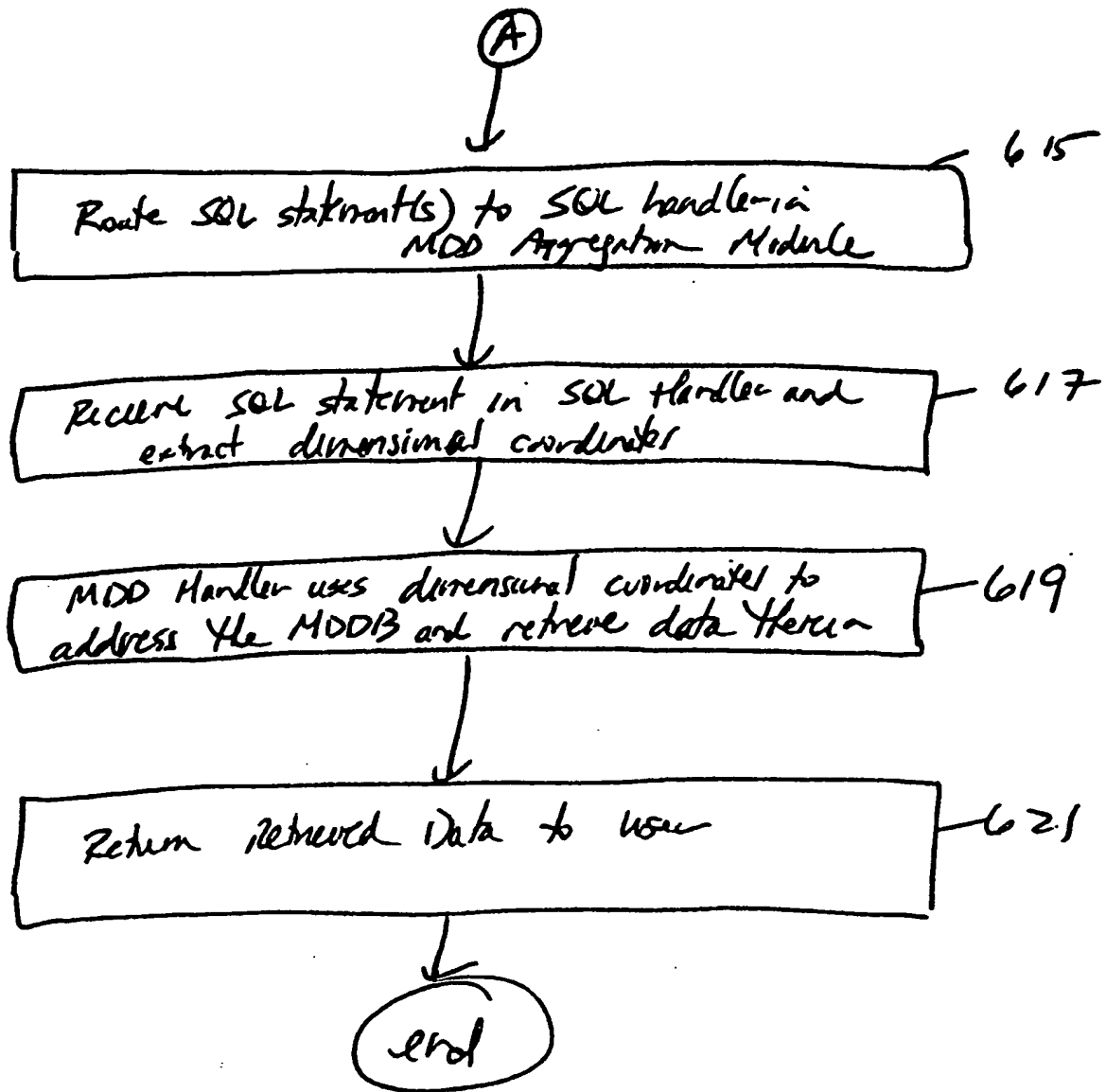


FIG. 19C(ii)

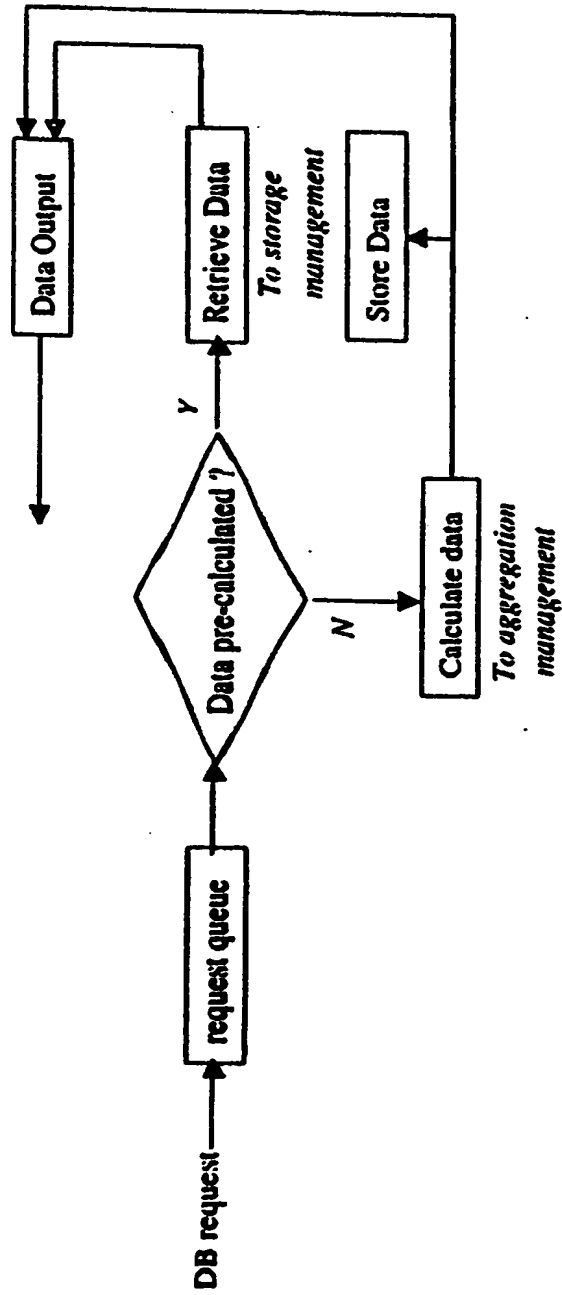


Fig. 19D

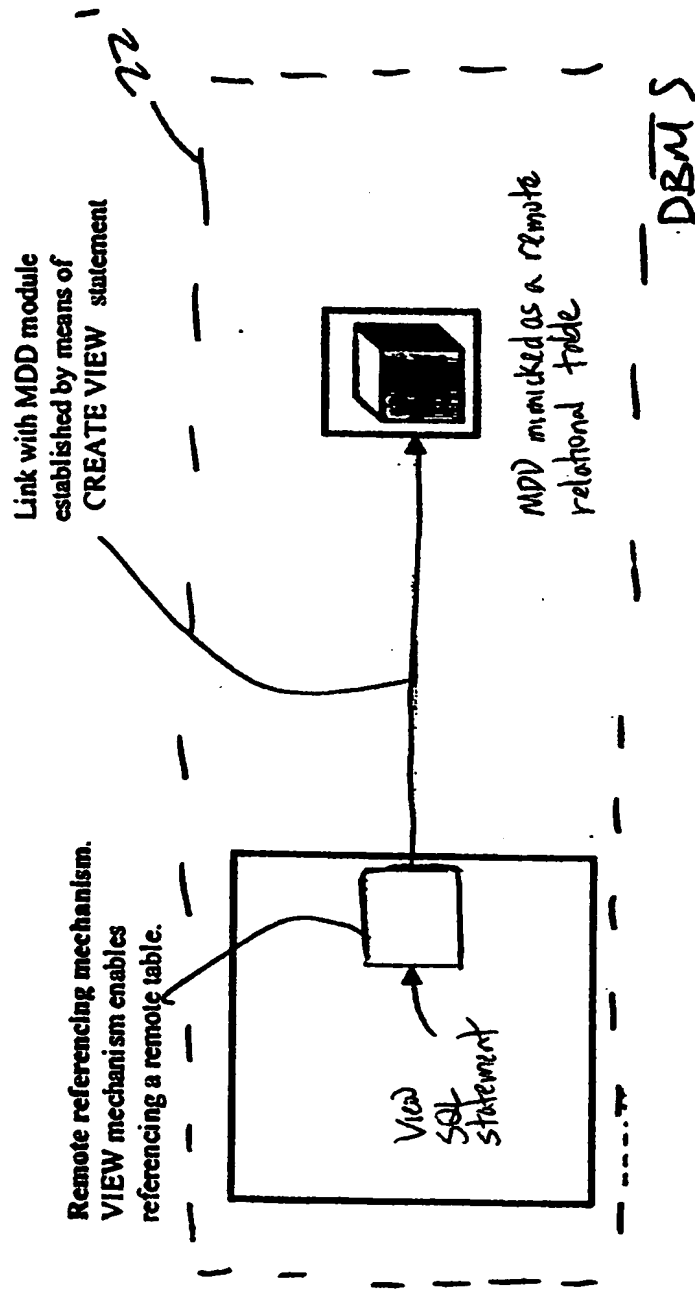


FIG. 19E

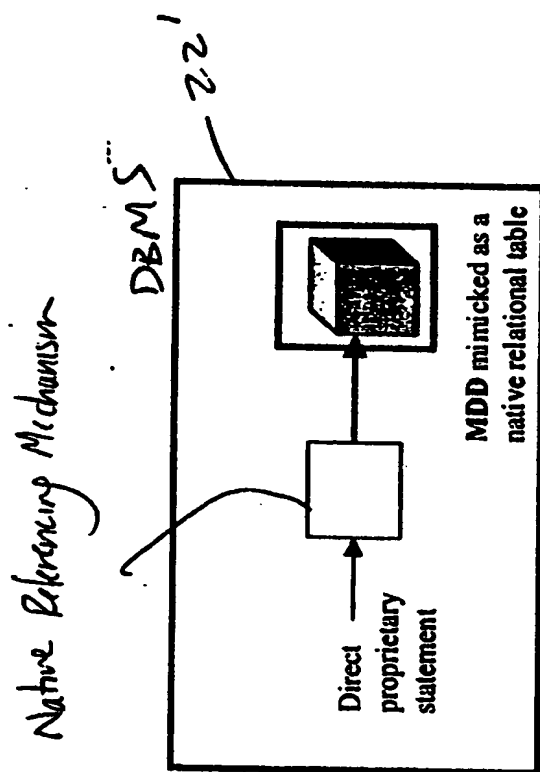


FIG. 19f

bh/bh

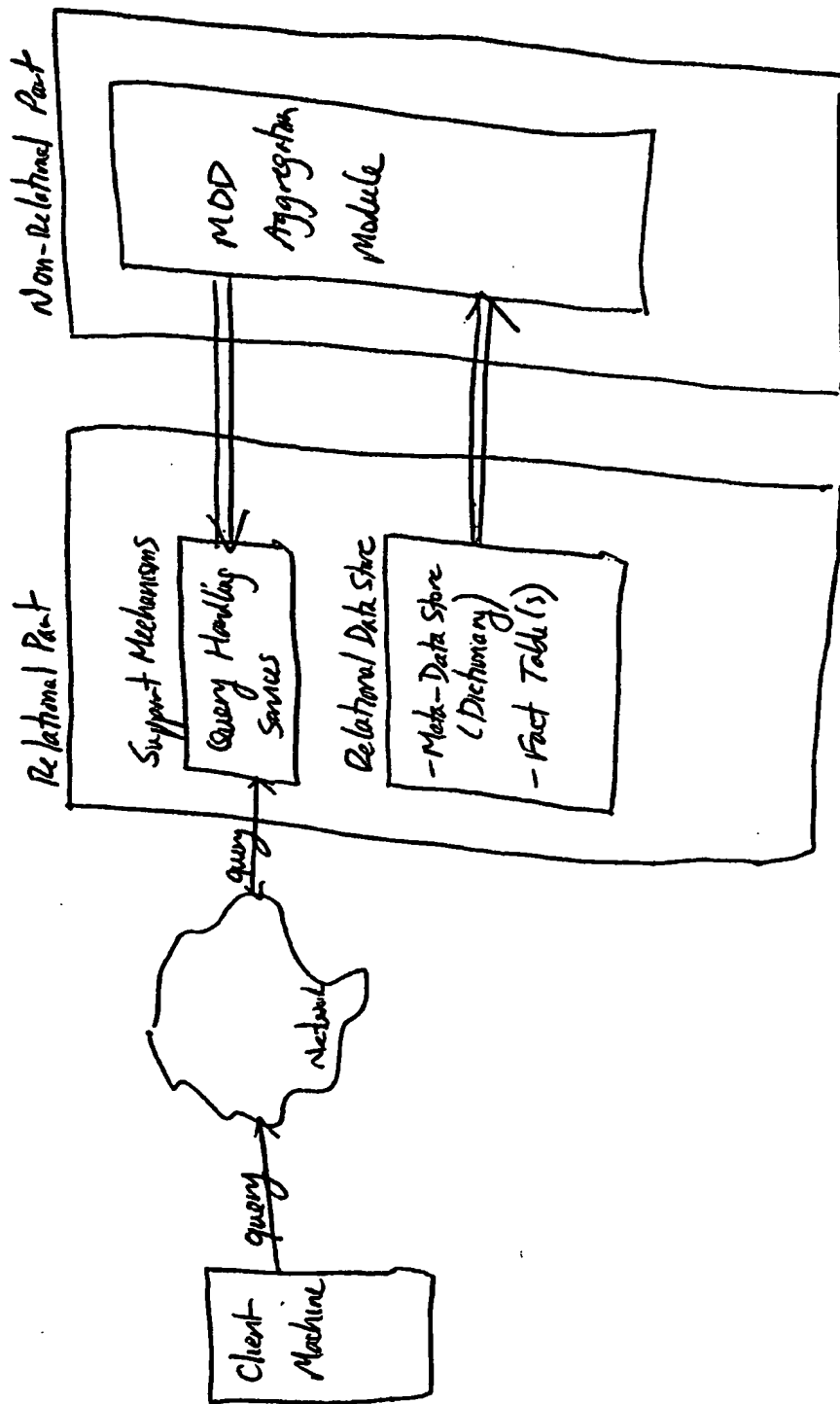
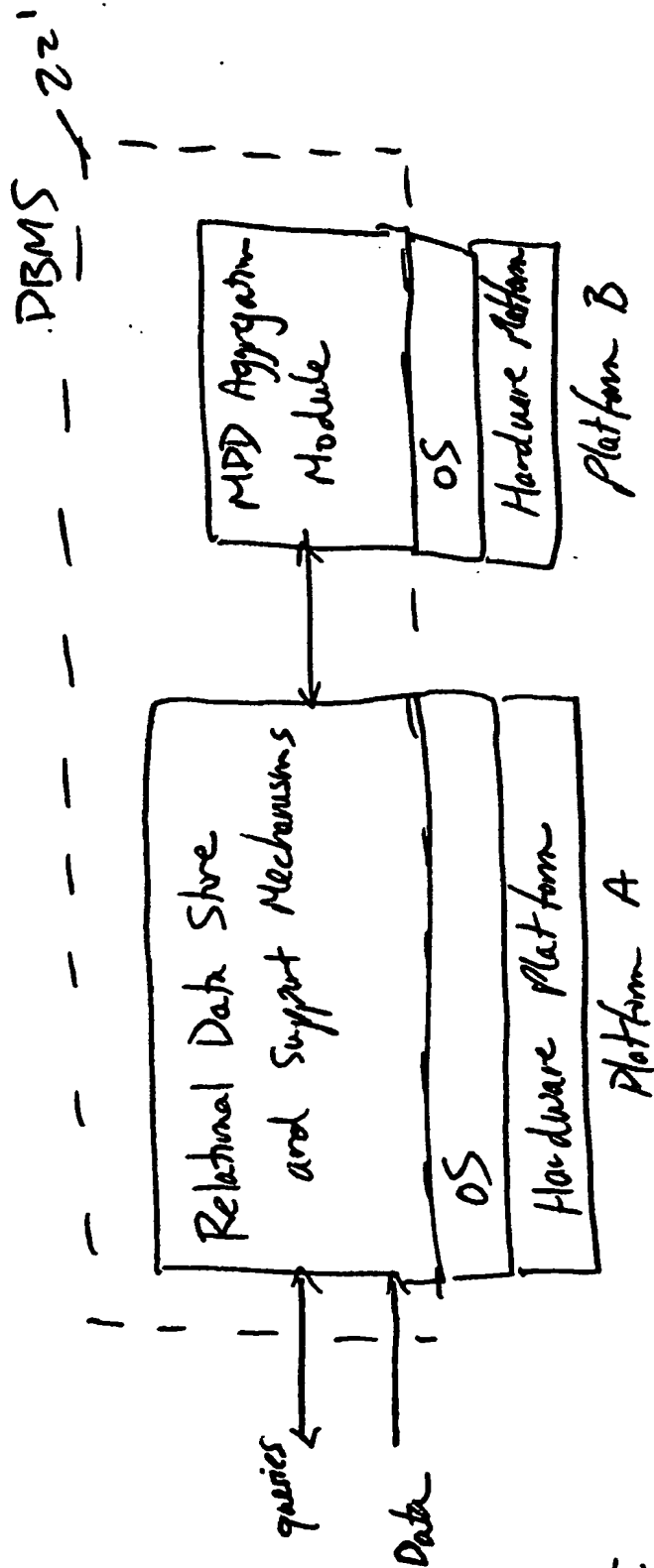


FIG. 19G

45/49



6/7/9.

FIG. 20A

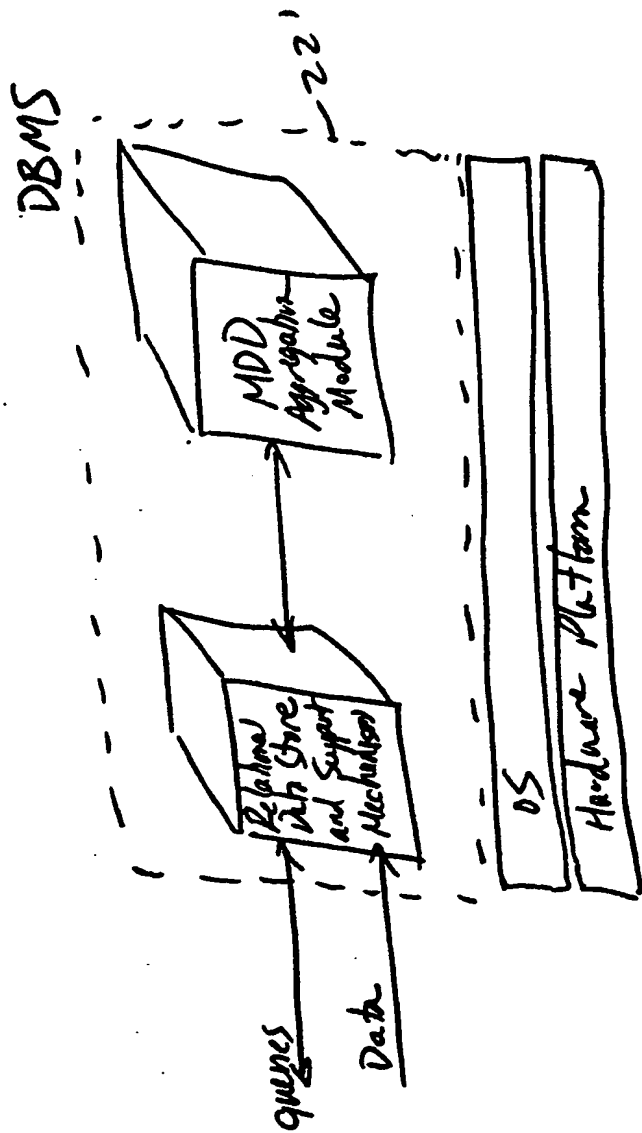


FIG. 20B

44/17

# Data Warehouse RDBMS

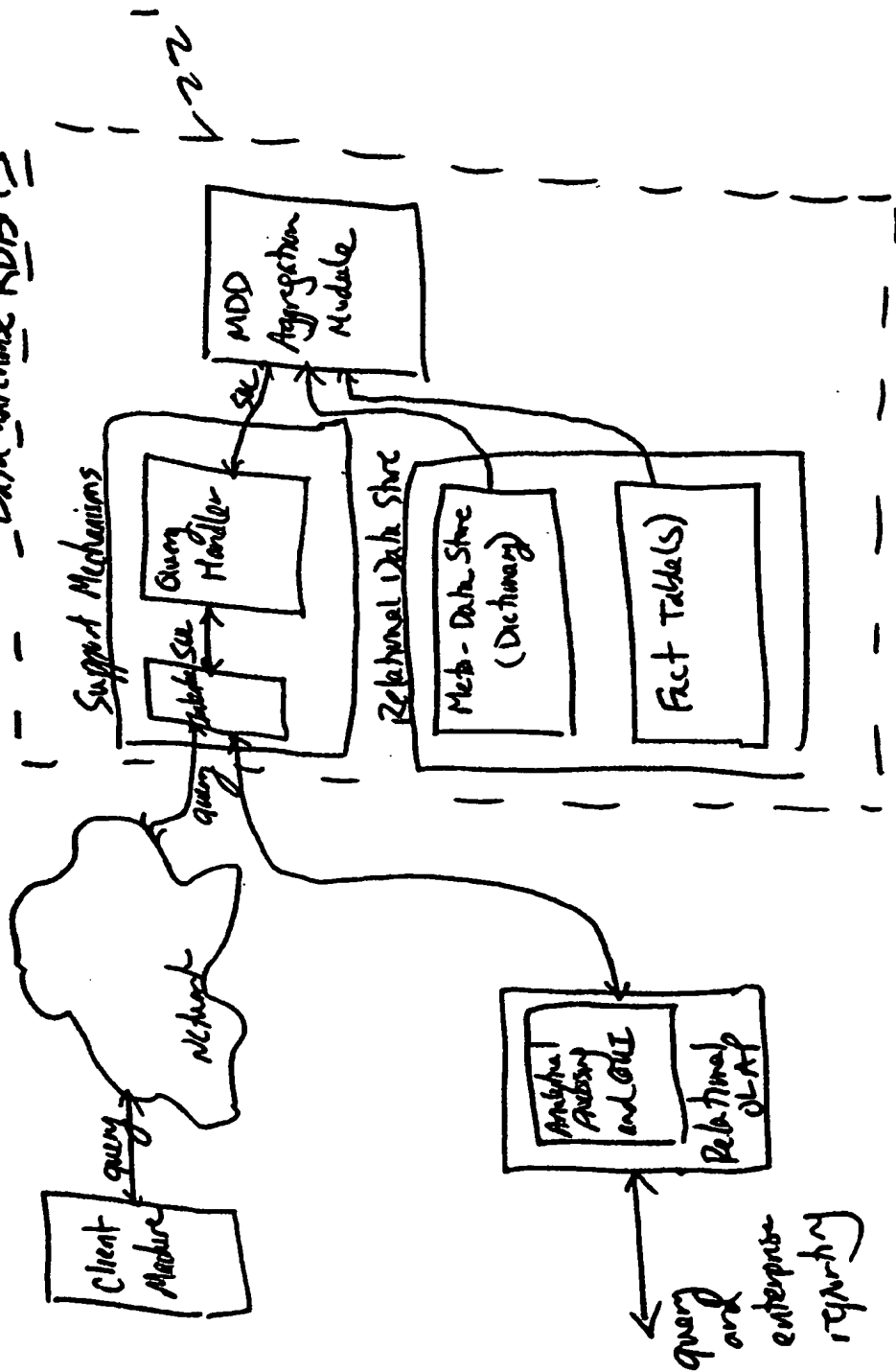


FIG. 21



# Data Warehouse - OLAP RDBMS

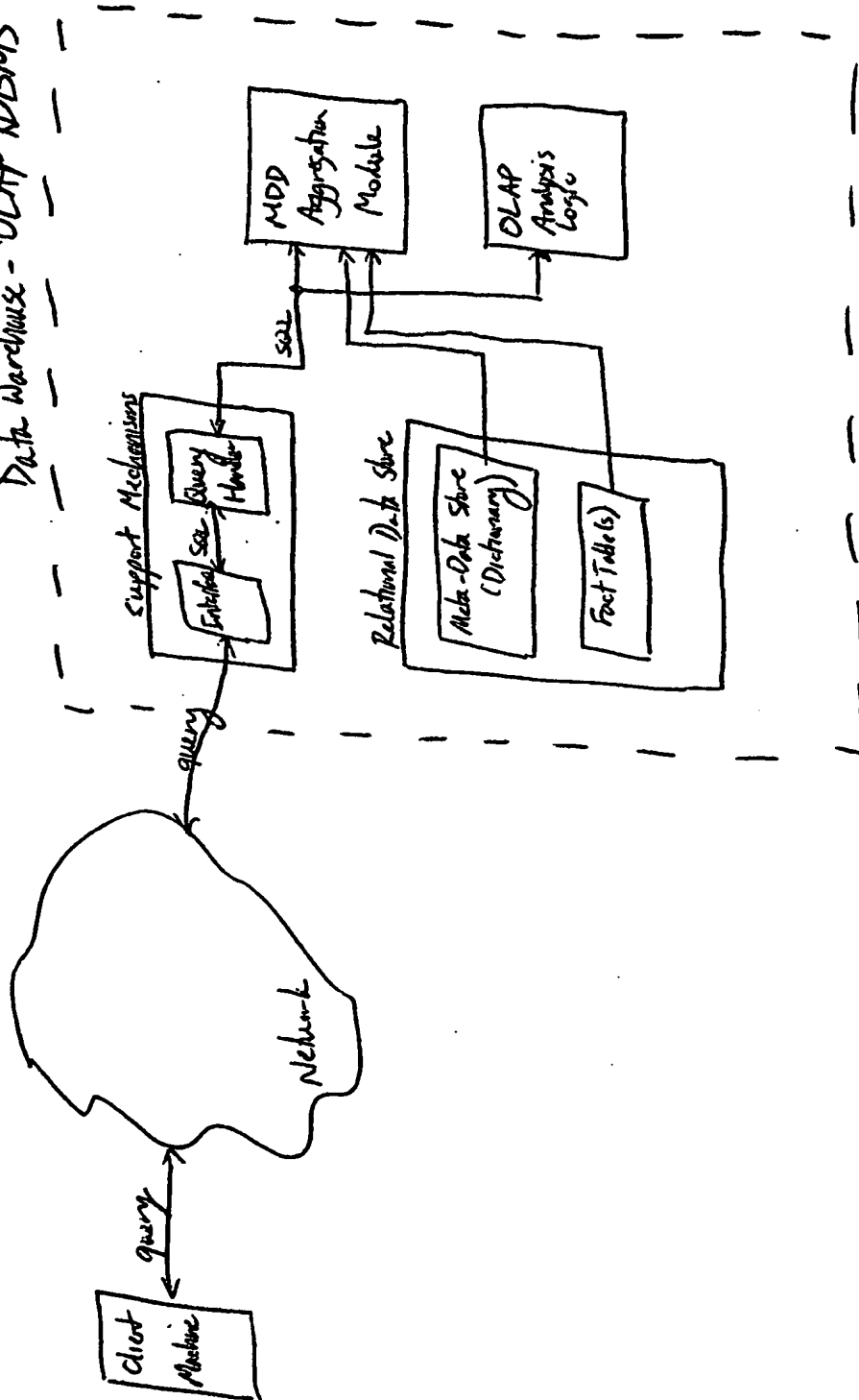


FIG. 22